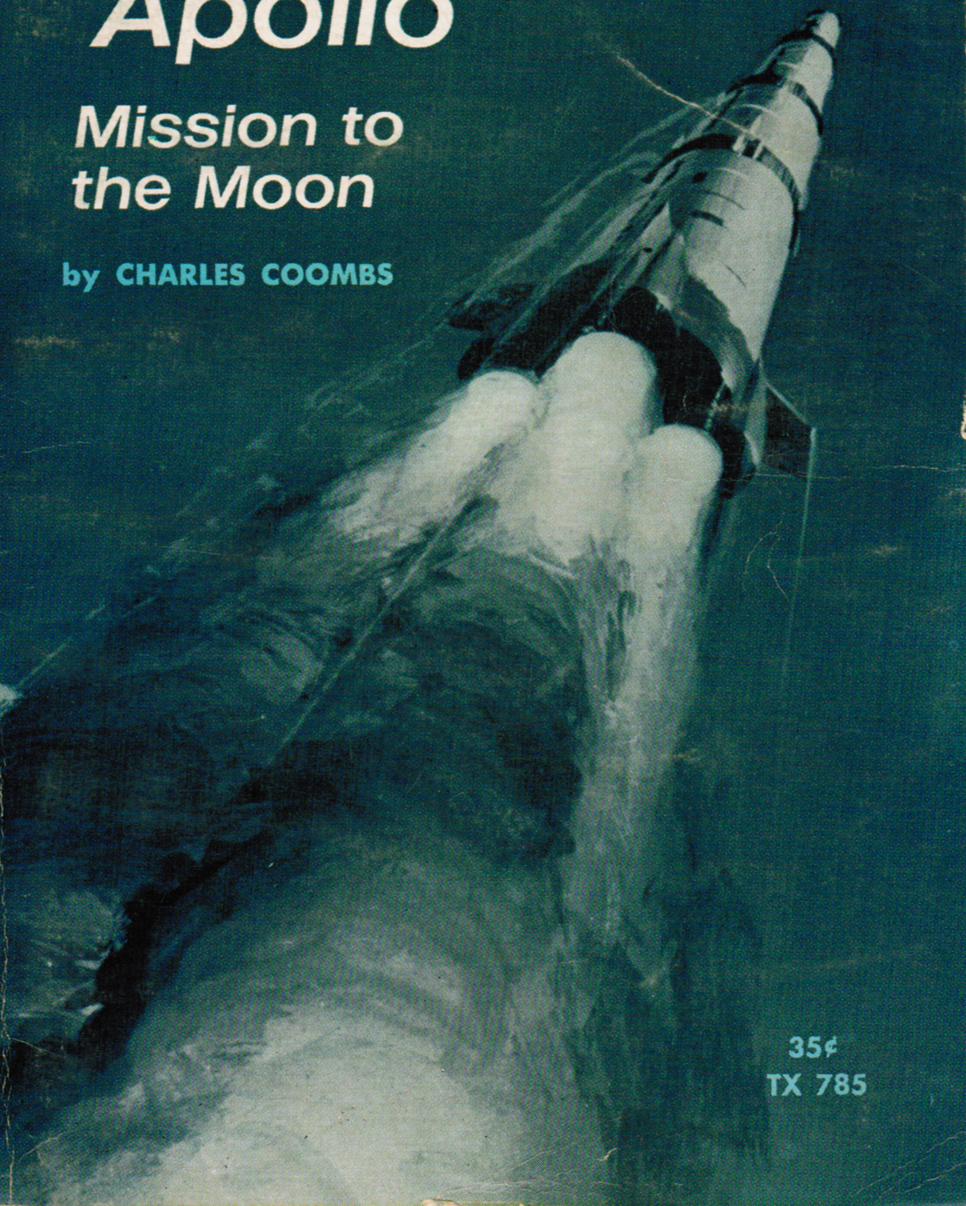
Project Apollo

Mission to the Moon

by CHARLES COOMBS



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Mission to the Moon

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With Photographs, Illustrations, and Diagrams

SCHOLASTIC BOOK SERVICES

Published by Scholastic Book Services, a division of Scholastic Magazines, Inc., New York, N. Y.

2nd printing . . . . October 1967

Printed in the U.S.A.

ACKNOWLEDGMENT

My thanks to Space and Information Division of North American Aviation, Inc., and to Earl Blount for furnishing the major Project Apollo data, as well as for providing the artwork used inside this book. Also many thanks to the National Aeronautics and Space Administration (NASA) and Stan Miller for helping me check out the basic facts of the book. However, since this space program deals largely in unknowns, these facts are subject to adjustment almost until the final moment of pushing the launch button.

CHARLES "CHICK" COOMBS
Los Angeles, 1965

Contents

1. The Mission

The purpose of the Project Apollo mission is to transport three astronauts on a quarter-of-a-million-mile journey to the moon, and to bring them safely back to Earth. No such daring, costly, and significant mission has ever been attempted before.

At best, Project Apollo will open the door to new worlds in outer space – worlds that can be explored, developed, and perhaps even colonized by future generations.

At worst, outer space may stubbornly resist man's attempts to solve its mysteries and survive its hazards. The moon's environment is hostile to man. It completely lacks the essential elements needed to support human life. It is possible, although not probable, that conditions on the moon are sufficiently harsh to prevent man from planting his boots safely upon its surface. Even should this prove true, mankind

certainly will reap vast benefits from the research and development that go into the heroic effort.

The Project Apollo mission to the moon is well under way. Allowing some leeway for last-minute changes which may be necessary as new knowledge is gained, there is a definite plan for the procedure of the mission.

Prior to the manned moon launch, a long list of preliminary missions must be completed. Ranger and Surveyor rocket-launched probes will explore the moon by orbiting it and sending back televised pictures and assorted electronic data. Some of these vehicles will land on lunar soil. Automatically they will take samplings of dirt, rock, or ash, diagnose their physical properties, and relay the results back to Earth.

Still other unmanned probes will place automated "lunamobiles" on the moon. Remotely controlled, they will prowl the mountains and craters on spidery steel legs or on inflated balloon-type rollers. En route to the moon, these probes will also gather important data about the properties and hazards of cislunar space, that mysterious void stretching from the Earth to the moon.

Both unmanned and manned Apollo spacecraft will make low exploratory passes over the lunar surface. Some will orbit the moon several times and return

home without landing. They will gather vast stores of important information.

Assuming the day arrives when this information is complete, the moon-landing mission will proceed according to the following plan:

A three-stage Saturn-V booster rocket begins to take form. Piece by small piece, part by giant part — by plane, train, truck, and barge — it has arrived at the John F. Kennedy Space Center, located midway up the east coast of Florida. This is the nation's 90,000-acre spaceport, which rises from the low, sand-filled swamps of the Merritt Island Launch Area, ten miles north of Cape Kennedy.

Complex 39 of the Merritt Island Launch Area, where future U.S. spacecraft ventures will originate.

The rocket is built atop a baseball-diamond-sized mobile platform, which stands on massive supports some twenty-five feet above the floor of a vertical assembly building. Mounted on the platform beside the rocket is the 400-foot-tall umbilical tower. Between it and the rocket stretch masses of wire, cables, pipes, and hoses. Through these external feed lines the rocket can be constantly checked and inspected until the final moment of the lift-off.

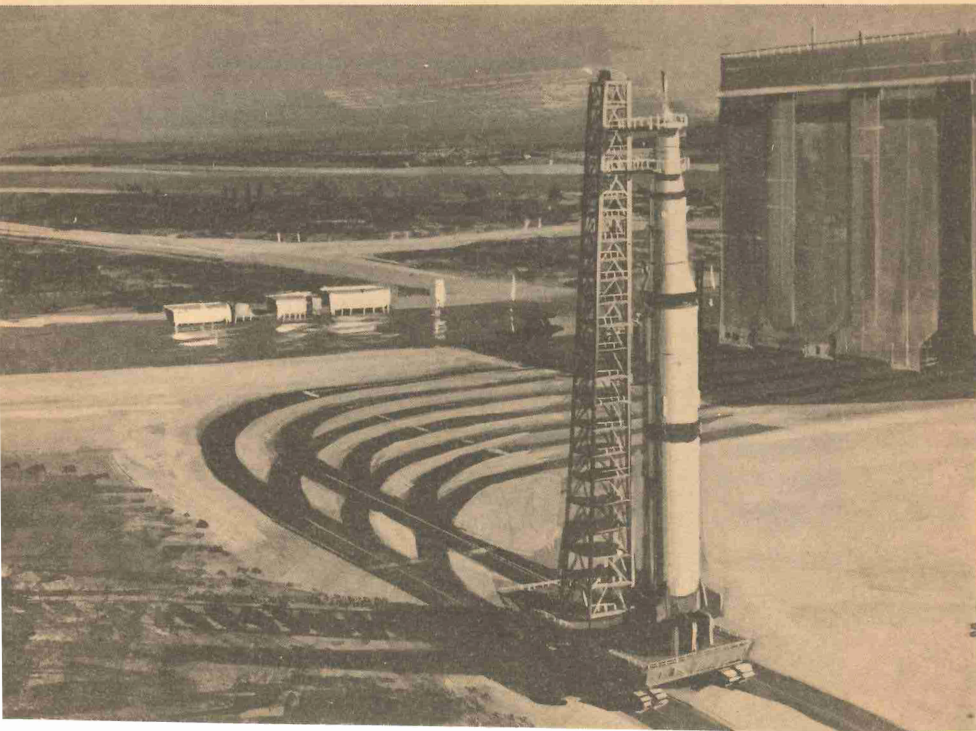
As the Saturn-V booster grows inside the vertical assembly building, each part is carefully checked by the maze of electronics which forms the Launch Control and Check-out System, located in a dustless air-conditioned building nearby. Similarly, every item of the Apollo spacecraft itself undergoes a continuous and most exacting check-out and inspection.

Now Saturn-V stands upright inside one of the high-roofed bays of the vertical assembly building. This building is one of the world's largest man-made structures. It has to be. From the bottom of the Saturn booster's five giant first-stage nozzles to the tip of the escape tower jutting from the Apollo spacecraft perched high overhead, the total vehicle measures some 380 feet in height. This is considerably taller than the Statue of Liberty, from foundation stones to the tip of torch. Yet the entire Saturn-Apollo

combination fits nicely inside the vertical assembly building, with plenty of headroom to spare. In fact, there is sufficient room in the bays to handle the assembly and check-out of several Saturn-V boosters at the same time.

The towering Saturn-V is the largest and most powerful piece of thrust-producing machinery the United States has ever designed and put together. It has been worked on by thousands of men and women

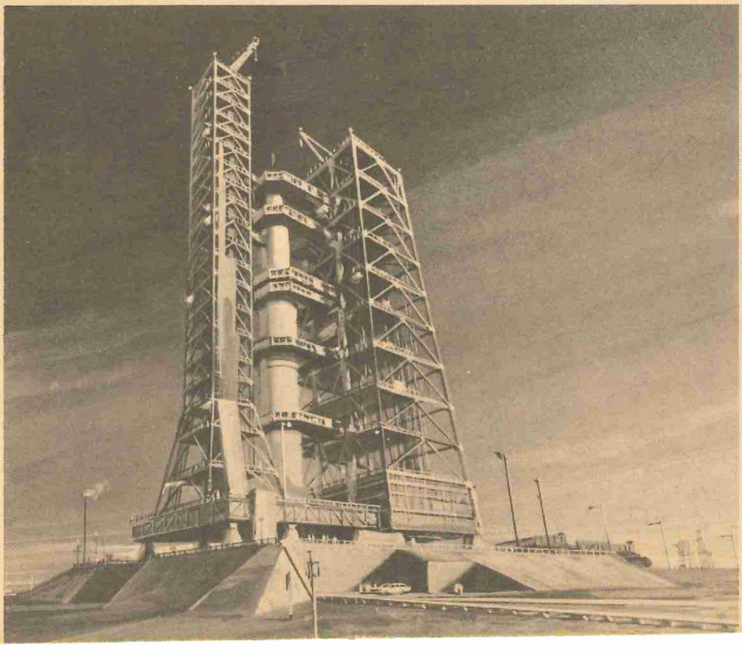
A massive crawler transports the Saturn-Apollo vehicle and the umbilical tower from the vertical assembly building to the launch pad.



in hundreds of shops and factories scattered throughout the country. Combined with the spacecraft on top of it, the three-stage rocket booster makes up the main "hardware" for Project Apollo.

At last the mammoth space vehicle is ready to start its three-mile journey to one of the special launch pads included in Complex 39, the jumping-off place to the moon. A powerfully built caterpillarlike crawler, mounted on eight massive rubber tank treads, moves in under the platform. With a prodigious feat of weight lifting, it picks up the entire launch platform holding the Saturn-V vehicle and the umbilical service tower. Slowly the crawler moves out of the vertical assembly

The final few days of the countdown take place on the pad.



building and follows along a specially constructed roadway toward the launch pad.

A few hours later the mobile platform is spotted and leveled in its proper place on the raised launch pad. The crawler moves away to an arming tower, parked about a mile from the pad. Soon the pipes, cables, and other umbilical-tower apparatus are hooked up to underground sources of power.

Since the major check-outs and inspections have taken place while the Saturn-V was in the vertical assembly building, the vehicle is virtually ready to go. The final few days of the prelaunch countdown get under way.

2. The Machine

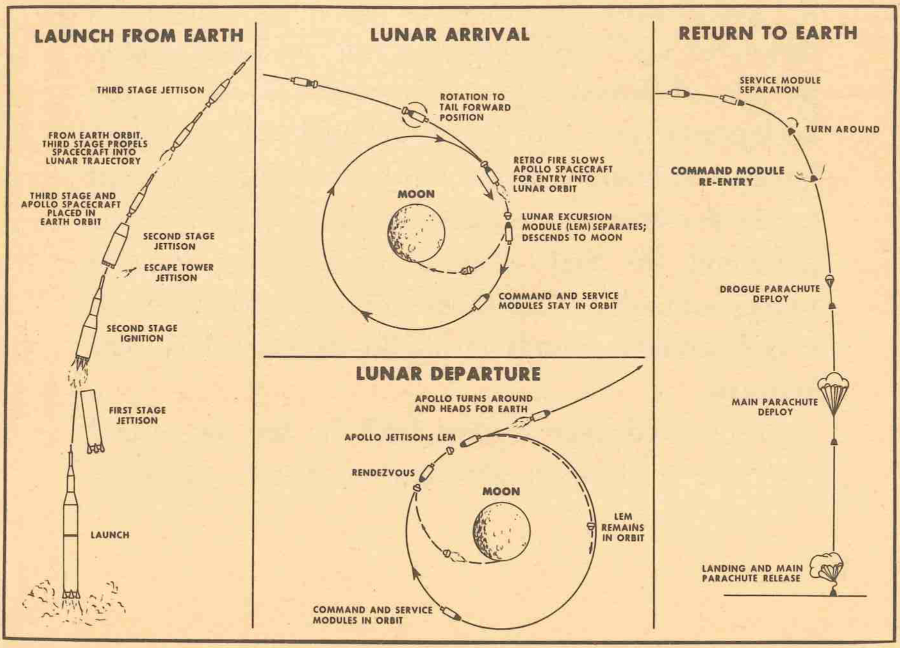
The tremendous size of the Saturn-V rocket booster and the Apollo spacecraft atop it seems to defeat the very purpose for which the Project Apollo vehicle is designed. That purpose is to break free from the Earth's gravity, to send 90,000 pounds of men and equipment to the moon, and to bring a small part of the vehicle, plus the men, back to Earth.

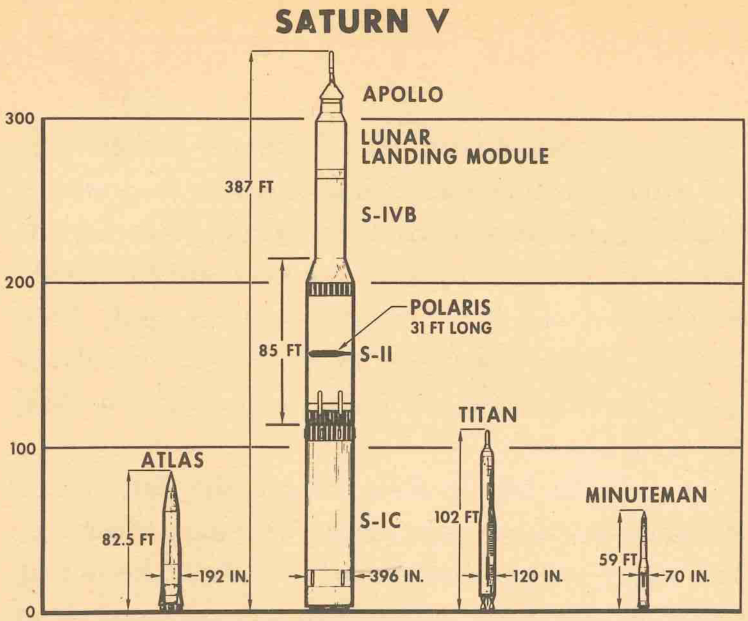
Filled with its massive load of propellants, the skyscraper-tall vehicle weighs approximately six million pounds, as much as a nuclear submarine. Since one pound of thrust will lift one pound of dead weight, it takes at least six million pounds of thrust to lift the Saturn-Apollo combination even an inch off the launch pad. To boost it safely into the sky and on its proper path into space requires much more thrust than that.

After this initial boost off the ground and through the atmosphere, another large amount of power is needed to accelerate part of the rocket and the Apollo spacecraft into a temporary orbit around the Earth. Finally, to send the forty-five-ton spacecraft itself hurtling toward the moon at an escape velocity of nearly 25,000 miles per hour requires still a third source of power.

In order to handle these chores, the Saturn-V is designed as a three-stage rocket. The main booster, or first stage, is designated the S-1C. Built by the Boeing Company, the S-1C is 33 feet in diameter and about 140 feet tall. It is made up of a cluster of five

Method of Project Apollo's round trip to the moon.





The Saturn V dwarfs all rocket boosters built before.

Rocketdyne F-1 liquid-fuel rocket engines. Since each F-1 engine generates one and a half million pounds of thrust, the S-1C has a total of seven and a half million pounds of thrust. This is roughly equal to the horsepower in a string of automobiles stretching bumper to bumper across the United States. Except for the five enormous exhaust nozzles, fuel pumps, and plumbing, the S-1C stage is made up of massive propellant tanks. To fill them requires nearly four and a half million pounds of liquid oxygen (lox) and kerosene.

The second-stage engine, built by the Space and Information Systems Division of North American

Aviation, Incorporated, is known as the S-II. As big around as the first stage, but not much more than half the length, the S-II offers something new in rocket power. It is made up of a cluster of five J-2 engines, each one generating 200,000 pounds of thrust.

The J-2 burns liquid hydrogen instead of kerosene. Liquid hydrogen provides at least a third more power, but it is an extremely difficult fluid to handle. Lox has a temperature of nearly 300 degrees below zero Fahrenheit, which presents problems enough, but supercold liquid hydrogen has a temperature of 423 degrees below zero Fahrenheit. At this temperature, air literally solidifies. In order to prevent the clogging of systems, all valves, tubing, and pumps must be purged of air before liquid hydrogen can be fed into the rocket engines. Nevertheless, the extra power and burning time obtained from the combination of liquid hydrogen and lox makes the effort of solving the problems worthwhile.

The third and final stage of the Saturn-V booster is the Douglas S-IVB. It is built around the basic power plant of a single J-2 engine with its 200,000 pounds of thrust. This engine can be throttled. That is, it can be shut down at any time, and restarted later when additional power is needed.

Such is the main propulsion system designed to

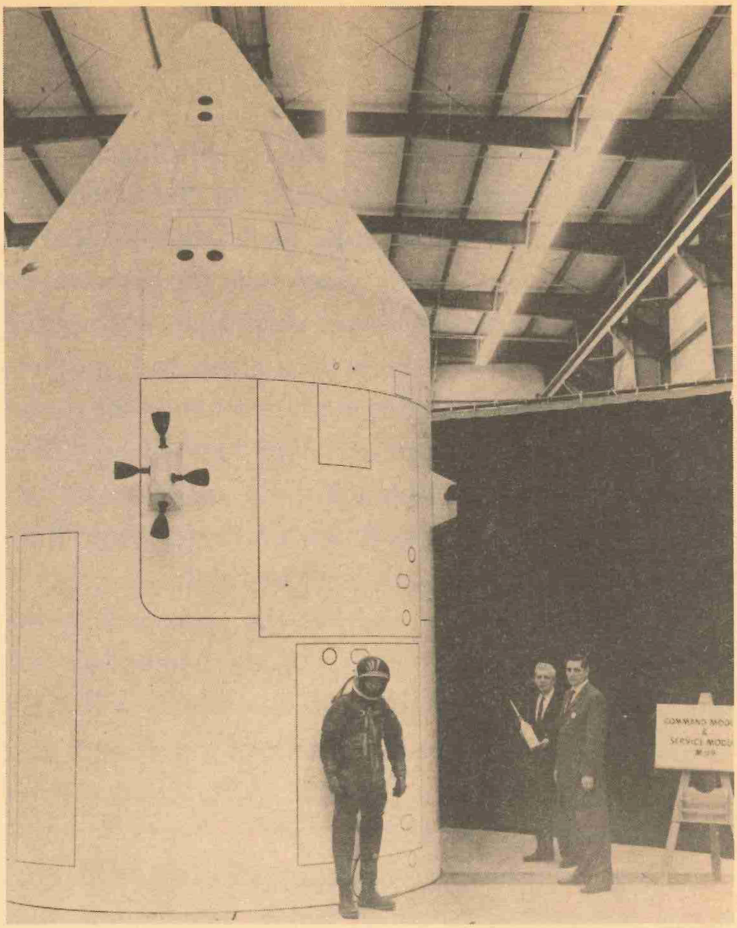
carry the Apollo spacecraft to the vicinity of the moon.

The Apollo spacecraft itself is made up of three major parts, or modules. It is about thirteen feet in diameter, weighs forty-five tons, and, including the emergency escape tower, stands about eighty feet tall.

The escape tower has a singular function. If anything goes wrong on the pad during the final minutes of the countdown, or during the early moments of the flight, the powerful solid-fuel rockets in the tower will fire and pull the manned capsule away from the top of the Saturn-V booster. They hurl it several thousand feet into the air and off to one side of the danger. Parachutes lower it gently back to earth.

Without the escape tower, the Apollo spacecraft itself is as tall as a five-story building. Its three separate modules, from top to bottom, are: the command module (CM), the service module (SM), and the lunar excursion module (LEM). The latter is commonly called the "bug."

The command module is the cone-shaped, pressurized capsule that carries the three astronauts on their trip to the vicinity of the moon and later returns them to Earth. Inside it are the instruments, the controls, and the life-support systems necessary to conduct a manned flight to the moon. The CM is approximately thirteen feet across its blunt base, and



A full-scale mock-up of the combined command and service modules indicates the general size of the spacecraft. Hornlike objects and black dots are ballistic control rockets.

a similar height to the pointed peak of its cone. It weighs about 8,000 pounds. Although it provides a minimum of elbow room, it will accommodate the

three astronauts without too much crowding.

Directly beneath and attached to the command module is the service module. Some thirteen feet in diameter and over twenty feet tall, the SM carries various items of guidance and propulsion not needed directly within the pressurized command module. Most important, the service module contains the rocket engine that can be throttled. This kind of engine is needed for the close approach to the moon, as well as for the final burst of speed needed to get away from the moon and on the path back to Earth.

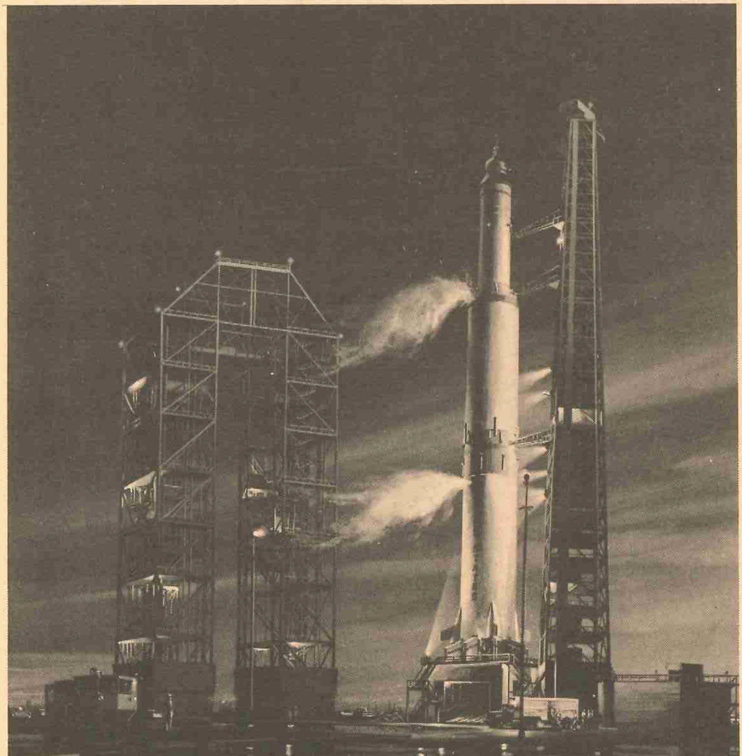
The bottom, or third part, of the spacecraft is the lunar excursion module. The LEM is a twenty-foot-tall, ungainly looking two-man vehicle, which will ferry two of the astronauts to the surface of the moon. Later it will shuttle the men back to the orbiting mother ship for the return to Earth.

As the countdown at Complex 39 reaches its final hours, everything seems in order. The crawler has brought the arming tower up beside the Saturn-V. So heavy are the various booster stages and spacecraft modules that considerable force will be required to shove them apart at the proper times. Different types of small rockets and pyrotechnic devices are strategically planted to do the job. Others are used as ballistic controls to change the spacecraft's position during

flight. Working from the arming tower, technicians carefully insert the explosive devices in place. Then the tower is rolled away again.

Soon supercold propellants are piped by the ton into the fuel and oxidizer tanks. Plumes of vapor spurt from safety valves as internal pressures build up.

The Saturn V comes to life on Pad B.



Electronic devices whir and hum. Not far away, in the windowless room of the Launch Control Center, engineers and technicians bend over dials and gauges, and peer into glowing radarscopes. Great banks of "black boxes" check out the rocket booster and the spacecraft. Everything gets the green light.

All systems are "go." The machine is ready.

But what about the men?

3. The Men

In the flight-crew quarters not far away, three astronauts are being helped into their form-fitting moon suits. Physically, mentally, and emotionally, these three men are far above average. They were carefully screened and thoroughly tested before being accepted into the astronaut program by the National Aeronautics and Space Administration (NASA). NASA guides and controls most of the United States' space activity, including Project Apollo.

All three astronauts come from the ranks of top-notch test pilots. Most of their flying time has been in high-speed jet aircraft. Each was less than thirty-five years old when he was accepted for astronaut training and sent to NASA's Manned Spacecraft Center near Houston, Texas, to begin training for actual space flight. Each has earned degrees in engineering or in the physical or biological sciences. And although they

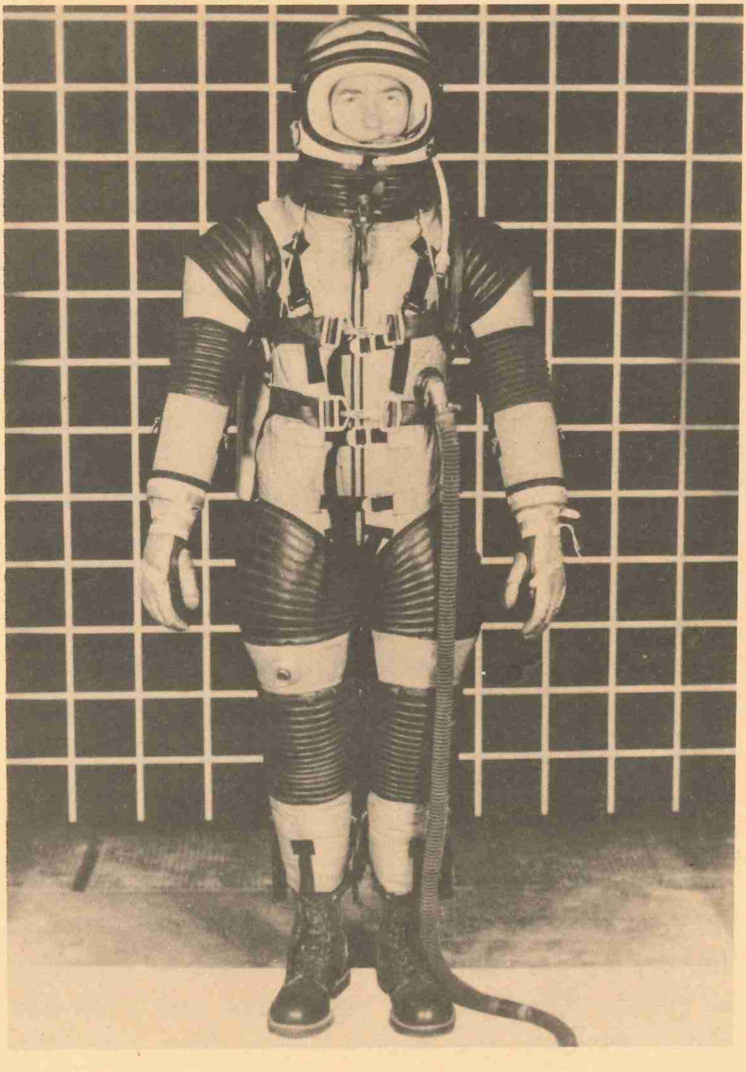
don't talk about it, each is extraordinarily courageous and strongly motivated by the desire, putting it simply, to "fly to the moon and back."

However, all the fine qualities these men possess are not nearly enough to get them to the moon. Physically, man remains the same unchanged mass of protoplasm that he was before the space age came into being. Since he is four fifths water, he is a soft and moist glob of cells, held together by a rather weak framework of bones. Too much pressure will squash him. Too little pressure will cause him to bloat like a balloon and, indeed, even burst.

He is sensitive to changes in temperature. He cannot long survive much more than a 100-degree variation from hot to cold. His life depends upon a steady supply of oxygen to breathe. Food and water, of course, are constant essentials.

In the endless vacuum of space, which begins where the thin film of atmosphere around the Earth ends, these vital items to human survival either do not exist, or they are completely out of normal balance. Caught a few miles away from his earthly environment, the unprotected body of a man is in most dire trouble.

Aware of this, yet not overly troubled by it, the three Project Apollo astronauts finish donning their tailor-made moon suits. These suits are designed to



A special space suit is essential to man's survival on the moon.

provide the astronauts with the necessary elements for survival: pressure to simulate that normally provided by the Earth's atmosphere, oxygen for breathing, ventilation, air conditioning, and at least a partial protection from harmful cosmic or solar rays, as well as from tiny bulletlike meteoroids.

Thoroughly briefed and properly checked out, the astronauts climb into a special van. It rolls slowly across the Merritt Island Launch Area to Pad B. There the Saturn-V glistens in the first light of dawn. White-smocked workmen, with brightly colored hard hats on their heads, are busy making final preflight tests. A constant stream of data flows into the Launch Control Center as, item by item, the towering space vehicle receives its final check-out.

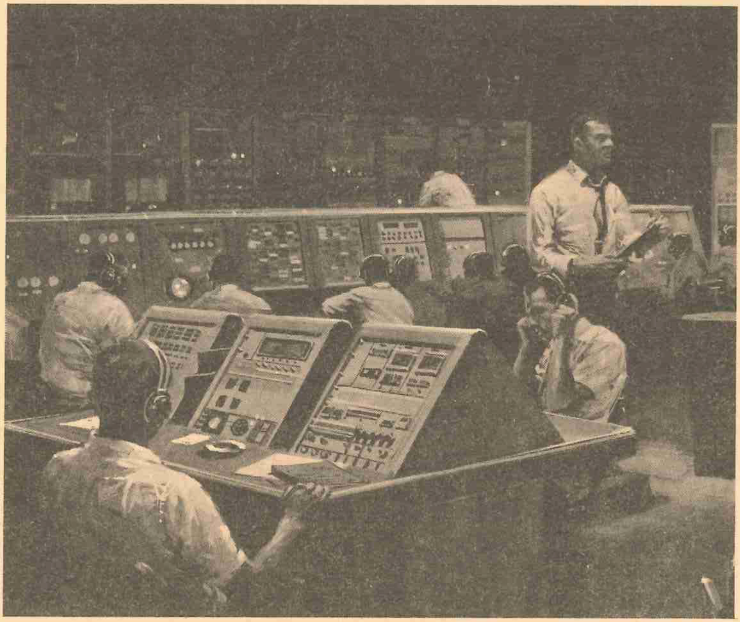
The van stops at the base of the pad. The three astronauts step out. They carry portable ventilation-and-support units to keep from perspiring or suffocating inside the space suits until they can hook up to the supply outlets inside the spacecraft.

Each man stands for a moment and looks up. Up, up, up, along the glistening shell of the Saturn-V. At the very top, the command module seems to be resting on clouds. They turn to each other and exchange smiles through the bulbous faceplates of their pressurized helmets.

Then they step into the gantry elevator which carries them up to the level of the command module. The hatch is open, waiting. They step across the platform. Willing and gentle hands help them squeeze through the hatch, one by one.

The commander-pilot settles himself in the form-fitting couch on the left. The navigator-copilot occupies a similar reclining seat on the right side of the conical capsule. The systems engineer squeezes

During the countdown and throughout the mission, technicians man the electronic consoles of control and tracking centers.



into his own contoured couch between them. As they lie on their backs, knees bent in a semisitting position, the commander and navigator can glance out of small heat-tempered windows, set into the side of the capsule. Other windows are directly over their heads, one on each side of the hatch.

In front of them, stretching from one side of the space capsule to the other, is an instrument-studded console. Other gauges and instruments are scattered in planned array around the capsule. They are of particular interest to the systems engineer, whose prime job it is to read and properly interpret them. Much of the gadgetry is hidden from sight beneath them and around the inside rim of the capsule.

In the upper tip of the cone, surrounded by the canisters into which are folded the recovery parachutes, is a tubular airlock compartment big enough to hold a man. It will have a definite use when the mission arrives in the vicinity of the moon.

Settled into their couches, the astronauts hook up the myriad hoses, wires, and sensors which not only will support life, but will provide a constant electronic log of their welfare and activity.

The capsule hatch is now closed and locked. Some of the technicians gently slap the outside of the spacecraft, as a signal wishing luck and success to the three astronauts inside.

Then they are alone. The countdown continues.

"T minus one hour!"

More checks are made, some by voice, some by automatic instrumentation. Below the astronauts the giant Saturn-V is coming to life. They can faintly hear the rush of propellants pouring into the huge tanks of the three stages. Metal crackles and pings as the supercold liquids torture it. They can feel the movement and vibration as thousands of tons of fuel and oxidizer boil and strain against the outer walls of the rocket.

"T minus thirty minutes . . . and counting!"

The astronauts smile at one another. But there is little time for contemplation, and less time for idle talk. There are things to do up to the very moment of lift-off. There will be more things to do after lift-off.

"T-minus ten minutes. All systems are *go!*"

The propellant tanks are topped off. Then the shrill whistle of escaping vapor ceases, as the safety valves snap shut and internal pressures build up in the propellant tanks.

"T minus one minute!"

The final moment has arrived. Nearly 400 feet below them a Niagara of water spews into the flame bucket, a giant trough that curves away beneath the five nozzles, each nine and a half feet in diameter,

of the first-stage F-1 engines. Without this insulation of water, the blazing inferno of heat would quickly melt the flame bucket and probably ruin most of the launch pad.

" . . . minus ten seconds, and counting!"

The metallic voice from the loudspeakers echoes off across the Merritt Island spaceport. High overhead the three semiprone men try to relax. They are only partially successful. But it doesn't bother them. They have earned the right to a certain amount of tension. It is not every day that someone sets off for a round trip to the moon.

" . . . six . . . five . . . four . . . three . . . two . . . one . . . *zero!*"

A flash of orange flame appears beneath the rocket.

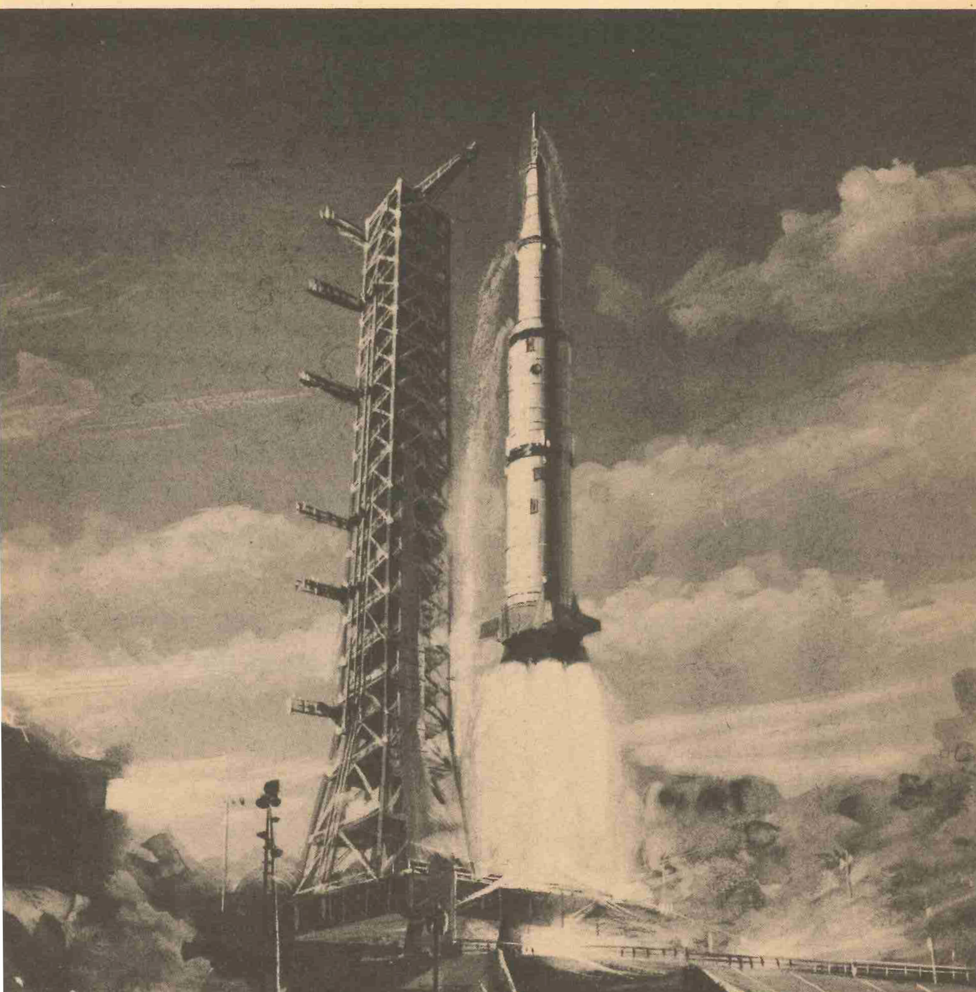
"Ignition!"

The rocket does not move. Nor is it supposed to. Not yet. This is preliminary fire. The propellant valves have not yet opened wide. The enormous turbine pumps have not yet begun to ram their full loads of fuel and oxidizer into the combustion chambers of the five F-1 rocket engines.

One second. Two seconds. Three . . . .

Now the flame reaches its peak, and the engines roar at full capacity.

"Main stage!"



Lift-off!

Land and sky tremble and reverberate as seven and a half million pounds of raging thrust try to raise the 3000-ton space vehicle from the pad.

Then the hold-down clamps snap back from the rocket. The mountain of aluminum and steel, of fuel and oxidizer, of electronics and engines, and, indeed, of flesh and blood, begins to move.

Again a single word crackles in the blockhouse and control center, and bounces across the sandy desolation that is part of the Kennedy Space Center. It travels with the speed of light to the Mission Control Center in faraway Houston and to the interlocking communications-and-tracking network spread around the world.

A single word, as the mighty Saturn-Apollo vehicle takes the first heavy step on its journey to the moon.

"Lift-off!"

4. Journey in Space

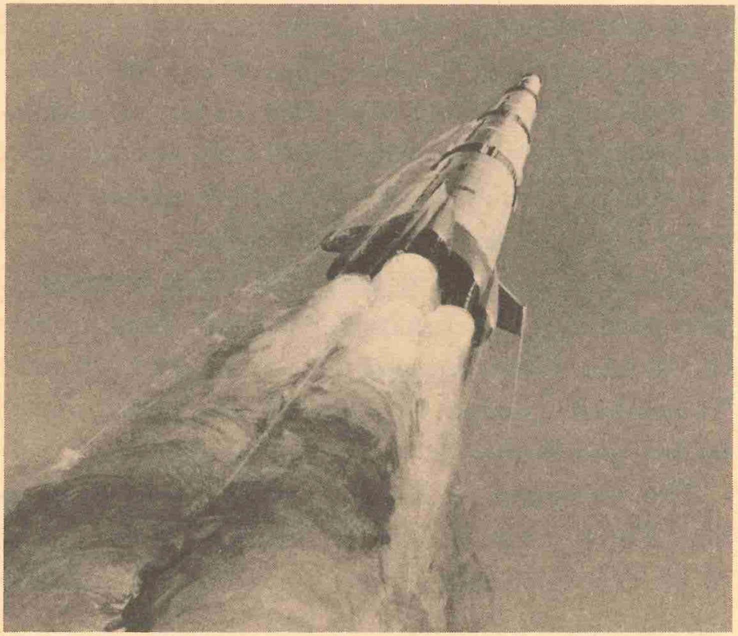
Despite the capsule's insulation and ability to absorb shock, the three astronauts are surrounded by noise and vibration. They wonder momentarily if all is going according to plan. They brace themselves. If anything is wrong, they can expect a sudden explosive tug as the escape tower automatically fires its solid rockets, and jerks the capsule skyward and away from the malfunctioning booster.

But there is no such tug. The clock is running. The mission is under way. Far beneath them a pillar of volcanic flame, burning fiercely at 5,000 degrees Fahrenheit, pushes the six-million-pound rocket farther and farther away from the pad.

The movement is barely perceptible to them at first. There seems to be more a feeling of sway than of lift. The guidance system works valiantly to keep the nose pointed straight up and steady.

Then, as velocity increases, the sensation of movement gets stronger. The force of the acceleration pushes the astronauts deep into their form-fitting couches, as gravity tries to hold them back. In effect, they soon weigh four and a half times what they would on Earth – or four and a half G's. This causes no great discomfort. They have withstood much greater G forces than this during their training days.

Seven and a half million pounds of thrust from the first-stage engines push the Saturn-Apollo vehicle skyward.



Their instruments and their information from ground control indicate that they are on proper course and bending gently on an arching trajectory eastward out over the Atlantic Ocean. The five F-1 engines gobble fifteen tons of kerosene and lox every second. But the Saturn-V first stage is successfully fulfilling its herculean task of propelling the spacecraft through the atmosphere, and at least loosening the sticky grip of Earth's gravity upon it.

Two and a half minutes later, at an altitude of thirty miles, the first-stage engines run dry. They automatically shut down. Retrorockets explode the empty rocket case away from the remainder of the vehicle. The case arches over and begins tumbling toward the blue ocean below. Inside the Apollo capsule the excessive G forces cease, and comfort returns to the astronauts.

Now the second stage ignites. The million pounds of thrust from its five J-2 engines continue to build up the vehicle's velocity. The load to be propelled is much less than before, since the first stage had accounted for more than three quarters of the Saturn-V's weight. Also, the atmosphere has thinned out with the increasing altitude. It no longer exerts a strong frictional force against the rocket.

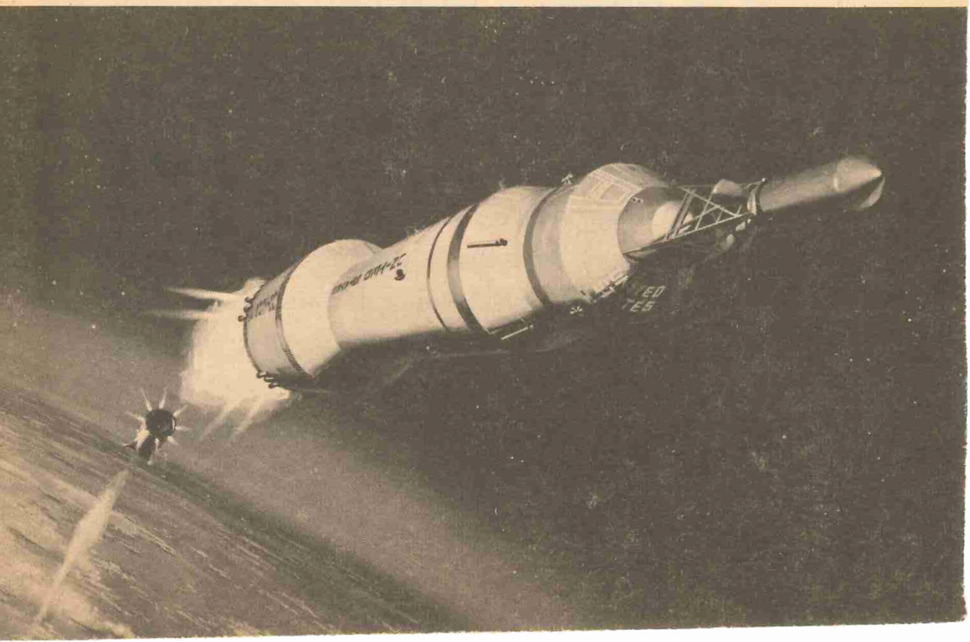
Shortly after ignition of the second stage the

astronauts both hear and feel the unused and now unneeded escape tower being jettisoned. They can see the downrush of flame as it fires away from the capsule.

For nearly five minutes the S-II stage adds its velocity to that already built up by the first-stage booster. During this time Apollo has been pushed to an altitude of approximately 100 miles. Its direction of travel has gently bent toward the horizontal, following the curvature of the Earth.

Now the exhausted second stage shuts down and separates from the remaining third stage and the space capsule connected to it.

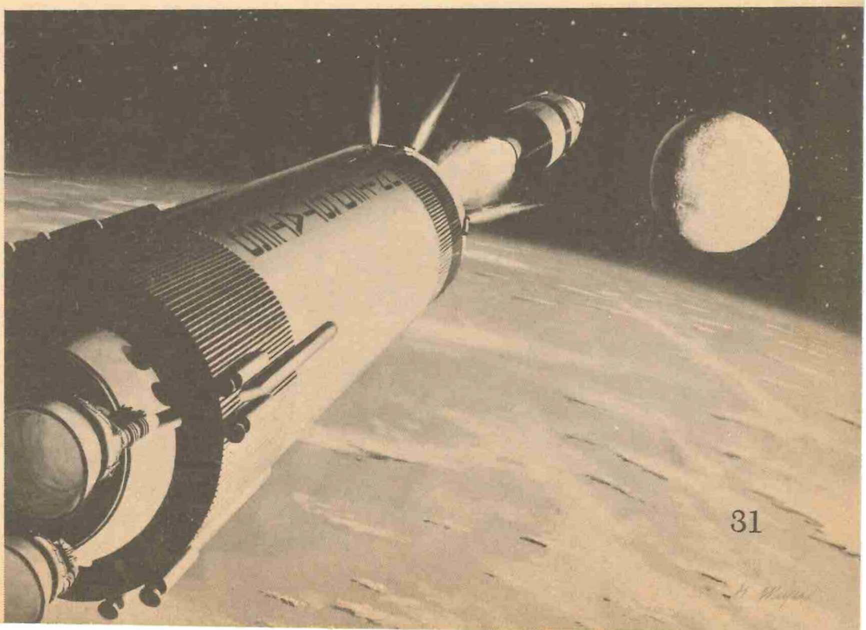
Just prior to jettisoning the escape tower, the second-stage engines take over.



Before gravity starts to pull the vehicle back toward Earth, the single J-2 engine in the S-IVB third stage fires up. The acceleration is barely noticeable to the astronauts. In fact, they feel a pull of gravity that is slightly less than on Earth.

For just under three minutes, the S-IVB keeps building up speed. When the velocity reaches approximately 17,500 miles per hour, the engine shuts down. Able to be restarted again at command, it stays attached to the spacecraft, conserving the remainder of its fuel for later. The third-stage engine and the three-module Apollo spacecraft are now in a coasting orbit 100 miles above the Earth.

The single J-2 engine of the third stage takes over after the second stage shuts down and separates.

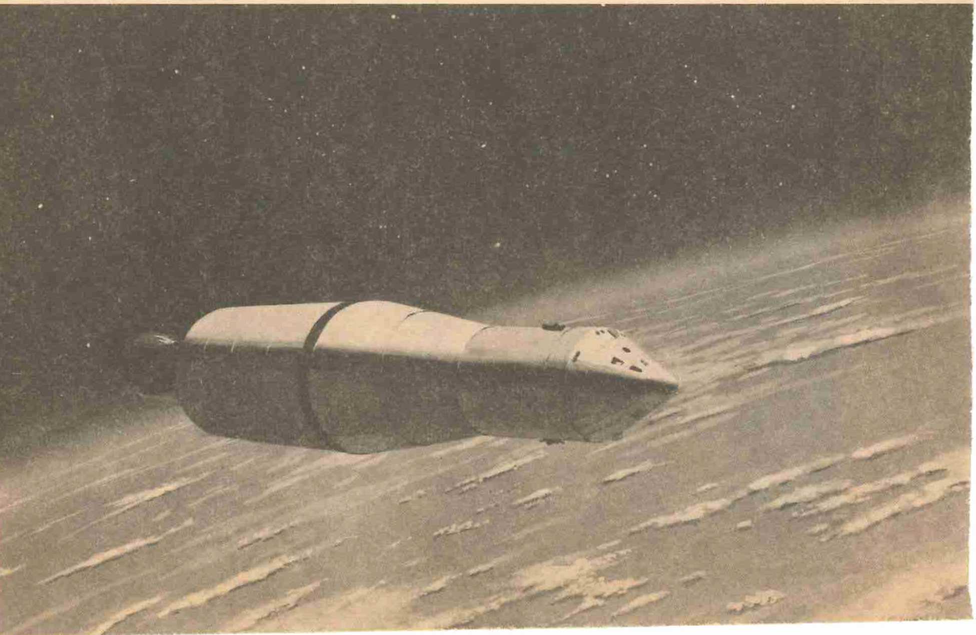


Suddenly the astronauts are weightless. Were they not strapped to their couches, they would float freely around inside the capsule. A loose clipboard with its check-out list drifts up in front of the copilot's eyes as though suspended by invisible threads. He reaches for it and nudges it with his gloved finger. It floats away. He makes another grab, gets hold of it, and stows it beside his seat.

"Apollo spacecraft." The words come through their headsets. "This is Mission Control Center. We have you now. Begin your check-out."

Things are working exactly according to plan. Until the Apollo spacecraft reached orbit, it was

Third-stage engine, shut down, and three-module Apollo spacecraft in coasting orbit around the Earth.



under the direction and control of the Launch Control Center on Merritt Island. Now, however, jurisdiction over the mission shifts halfway across the country to the NASA Manned Spacecraft Center in Texas.

There, in the Mission Control Center, dozens of technicians and countless fantastic computers and other electronic devices are working for the success of the mission and the safety of the astronauts. This is the hub from which the spokes of interlocking communication and control reach to all parts of the world and, indeed, deep into outer space.

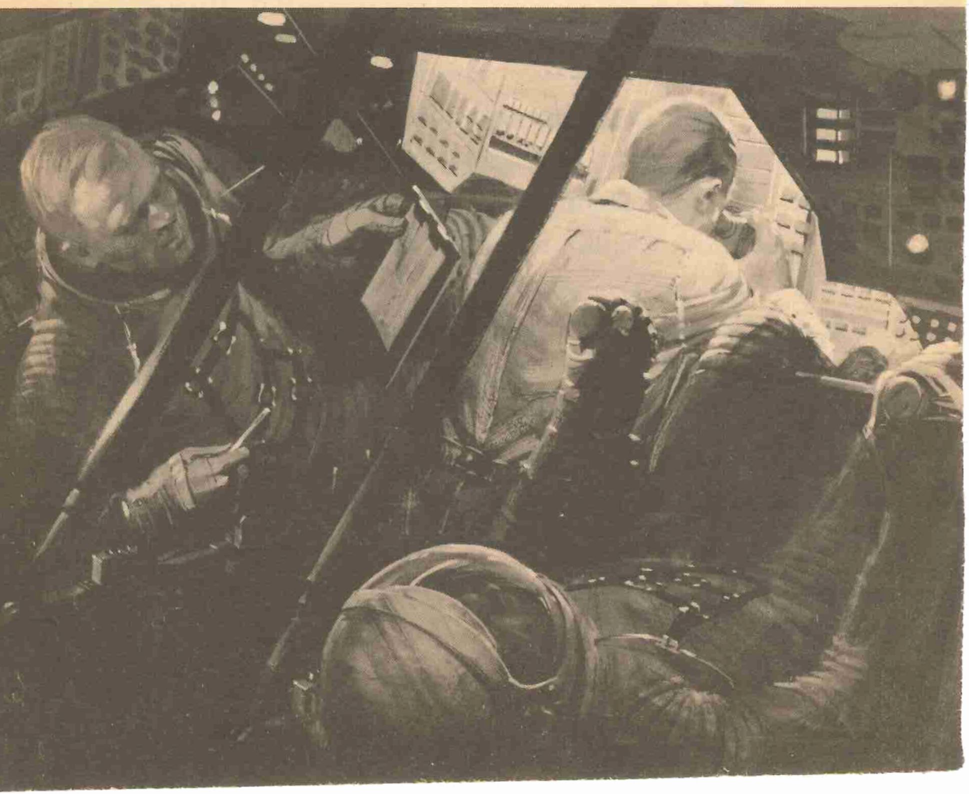
As the Apollo spacecraft continues on its coasting orbit around the Earth, the three astronauts proceed through their systems check-out. Two of them remove their helmets and loosen a few zippers in their moon suits to enable free movement. Space suits are not essential in the pressurized and air-conditioned Apollo capsule. However, one of the three always remains fully suited up and has his helmet in place. In case of an emergency, such as a pressure leak or a meteoroid collision, he can take control until the other two button up and don helmets.

The men check out the spacecraft, box by box, system by system. Down on the ground, the computers at the Mission Control Center are digesting radar data and other items of assorted information. Before

they can give the Apollo spacecraft permission to continue on toward the moon, computers must come up with the answers to some complicated questions.

For instance, since the journey to the moon will take approximately three days, they do not aim at the moon, but at the point where they figure the moon will be three days hence. Knowing that the moon moves at a speed of about 2,200 miles per hour around the Earth, this seems simple enough. But the moon is

The astronauts perform their systems check-out while in orbit.



not always constant in its orbit. Its orbit is not round, and it even has slight surges in speed. The Earth too is moving at a velocity of 67,000 miles per hour relative to the sun.

Also there is gravity, both the Earth's and the moon's, exerting a tug upon the spacecraft and alternately speeding up and slowing down its journey through cislunar space.

Still, by the time the astronauts have been in their Earth orbit for a couple of hours and have completed their systems check-out, the answers are ready.

"Everything okay out there?" an earthbound voice asks.

"Roger."

Had everything not checked out properly, the astronauts would have scrubbed the mission right then and there. They would have returned to Earth in much the same manner as the Project Mercury astronauts before them.

But things are right. The first phase of the mission has proceeded exactly according to plan. Now it is time to initiate the second phase – the 240,000-mile dash to the moon!

5. Crossing the Void

All necessary navigational data is at hand. By using the small control stick jutting from one of his armrests, the capsule commander triggers small ballistic-control rockets set around the outside of the orbiting spacecraft. The thrusts from spurting jets of steamy vapor roll and turn the coasting spacecraft until its pointed nose is aimed at the exact point in space where the moon will be in three days.

Then, at a precise moment, the third-stage booster engine blazes back to life. The renewed acceleration cancels out the weightlessness to which the astronauts were becoming more or less accustomed. Yet the vehicle leaves orbit and increases its velocity so gradually that the force of gravity is less than the normal one G.

For a little over five minutes the single J-2 engine of the third stage pushes the Apollo spacecraft faster

and ever faster – 20,000 miles per hour . . . 22,000 . . . 24,000 . . . .

At nearly 25,000 miles per hour, going away from Earth, the space vehicle reaches escape velocity. At that speed it overcomes the pull of Earth's gravity. The rocket engine shuts off. Again the Apollo spacecraft and everything inside it is weightless, coasting freely through space.

There is no longer any danger of falling back to Earth. Even though speed will steadily decrease as the spacecraft coasts moonward, so will the tug of Earth's gravity upon it decrease. It is as if a high-speed automobile cut its motor and coasted to the top of a hill before slowing to a stop. The Apollo spacecraft will coast to the top of the hill of Earth's gravity before its momentum is gone. Then it will start down the far side of the gravity hill – this time influenced by the moon's gravity.

During the long weightless journey to the vicinity of the moon, the astronauts have many functions to perform and many observations to make. They must keep a close check on cosmic radiation levels. They must be extra alert to the threat of sudden solar flares, which bombard space with dangerous high-energy protons capable of penetrating the spaceship with deadly effects. They must be careful of any kind of

spark or fire which could explode the pressurized oxygen inside the capsule. They must be prepared to deal with errant meteoroids which might come zipping through the sides of the capsule.

Many potential hazards are there in the airless void surrounding them. Yet they are the calculated risks that any astronaut accepts without undue anxiety. He cannot allow them to interfere with his work.

And work there is aplenty. One of the biggest and most exacting jobs is navigation. The copilot and the systems engineer busily take bearings on the Earth, moon, and stars. All of these are clearly visible in the dark backdrop of space. The astronauts transmit their findings to tracking stations on Earth, where they are matched with electronically computed navigational and guidance data.

The astronauts alternately work inside and outside their space suits. They stow the center seat and have enough room to stand. They can even move around a little and exercise. Periodically they eat and drink out of plastic squeeze bottles, or munch on cubes of prepared food concentrates.

They keep checking on their mental and physical condition, as well as on the condition of every item of operating equipment. They shoot pictures, record data, and make as many observations as they have

time for. They take turns sleeping and exercising.

There is another critically important job to do while they coast weightlessly through cislunar space. They use the S-IVB booster engine once again to make mid-course corrections in direction and velocity. Several such mid-course corrections must be made en route to the moon.

Once they are in a proper lunar trajectory, the astronauts have still another sensitive function to perform. Housed inside an adapter ring, located between the S-IVB booster and the service module of the Apollo spacecraft, is the lunar excursion module – the bug. It is now time for it to be positioned, so the men can transfer to it from the capsule when they reach the vicinity of the moon.

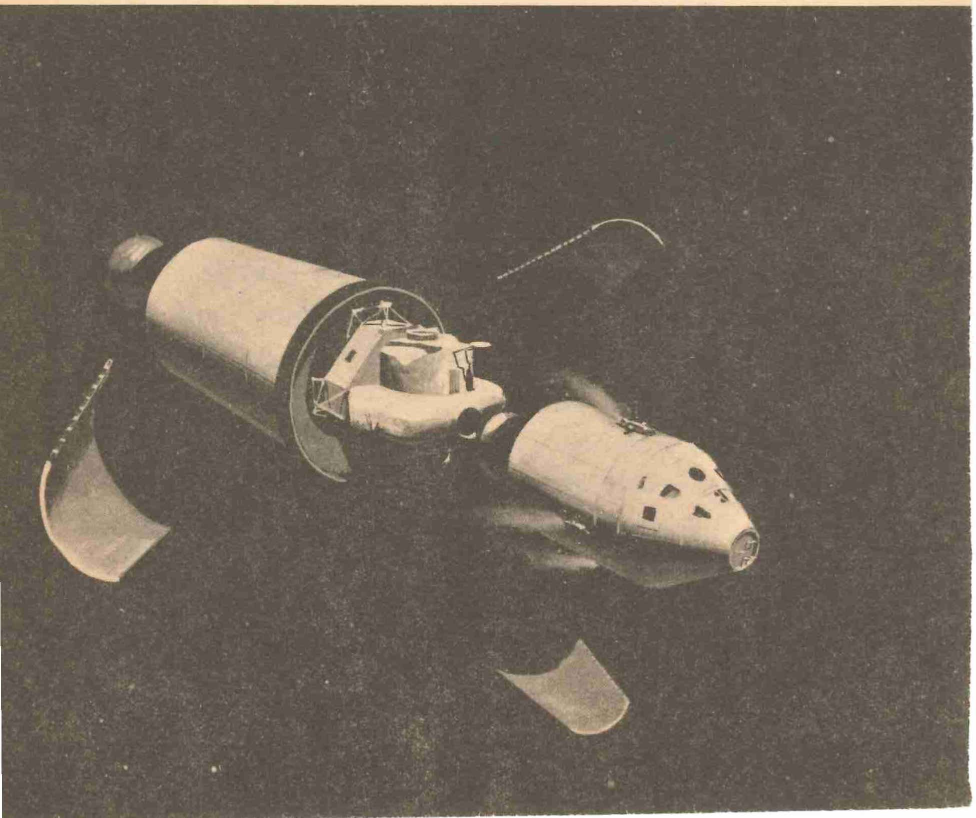
In order to make this transfer, the astronauts must hook up the bug to the nose, or upper cone, of the command module. But the large service module, with its rocket engine, its load of propellant, and an assorted array of other hardware, is between the bug and the command module.

Now comes the tricky maneuver. The part of the Apollo spacecraft that is made up of command module and service module breaks away from the third-stage booster, in the nose of which is nested the bug. Using the small ballistic jets protruding from

the sides of the service module, the Apollo commander carefully pivots the combined command and service module assembly a half turn in space. This brings the command module around, facing nose to nose with the bug. A little careful maneuvering closes the gap. The two modules hook up, and the two man-sized airlocks seal together.

The protective adapter panels around the bug break

Command and service module assembly separates from the spent third-stage rocket.

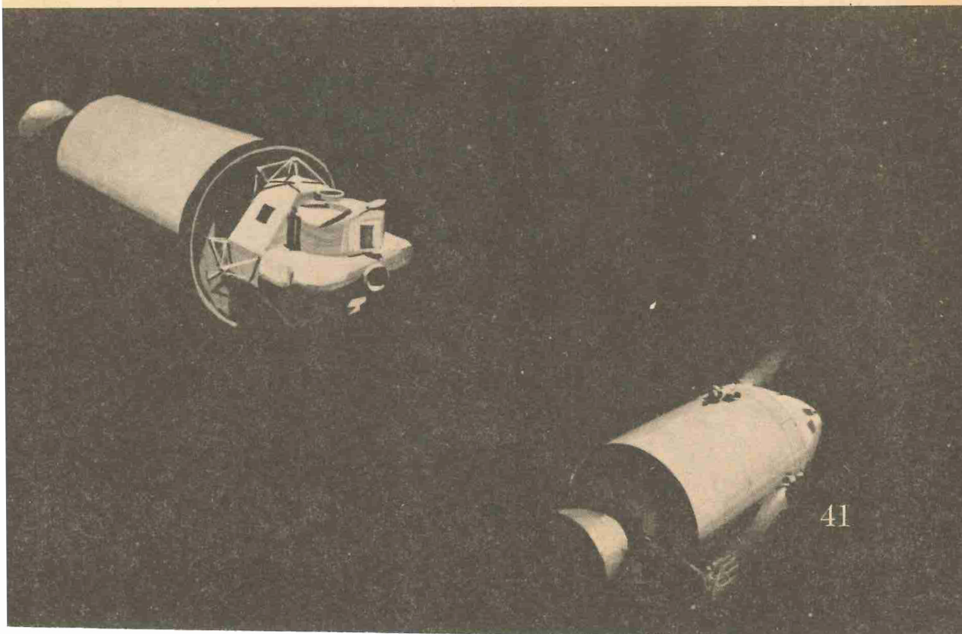


away. Its strange tubular legs unfold and spread out, ready for future use.

The unneeded third-stage engine case is now jettisoned. Aided by a few pyrotechnic devices, the men clear it from the path of the spacecraft, and slowly it drifts away.

It is not yet time for two of the astronauts to transfer into the bug for the purpose of making the landing on the moon. There are still many thousands of miles to go. The men do, however, make sure that everything is in readiness for the move. It is still not too late to cancel the moon landing if anything does not check out properly.

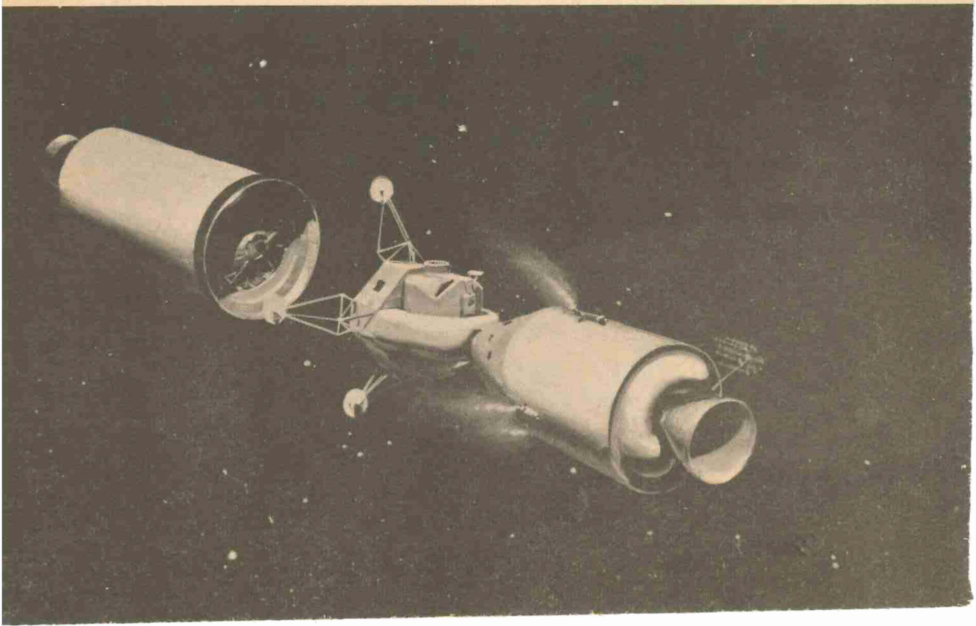
The Apollo spacecraft turns around in midspace and connects with the lunar excursion module.



With all systems working, the three connected modules of the Apollo spacecraft continue coasting moonward. Final mid-course corrections are made with short bursts of power from the 22,000-pound-thrust engine in the service module. Then, as they approach the moon, the astronauts use the ballistic controls once again to turn the spacecraft around until it is coasting backward.

The vehicle's speed has decreased substantially during the nearly three days of the journey through space. Yet, unless checked, the spacecraft's velocity still is sufficient to send it hurtling right on past the moon.

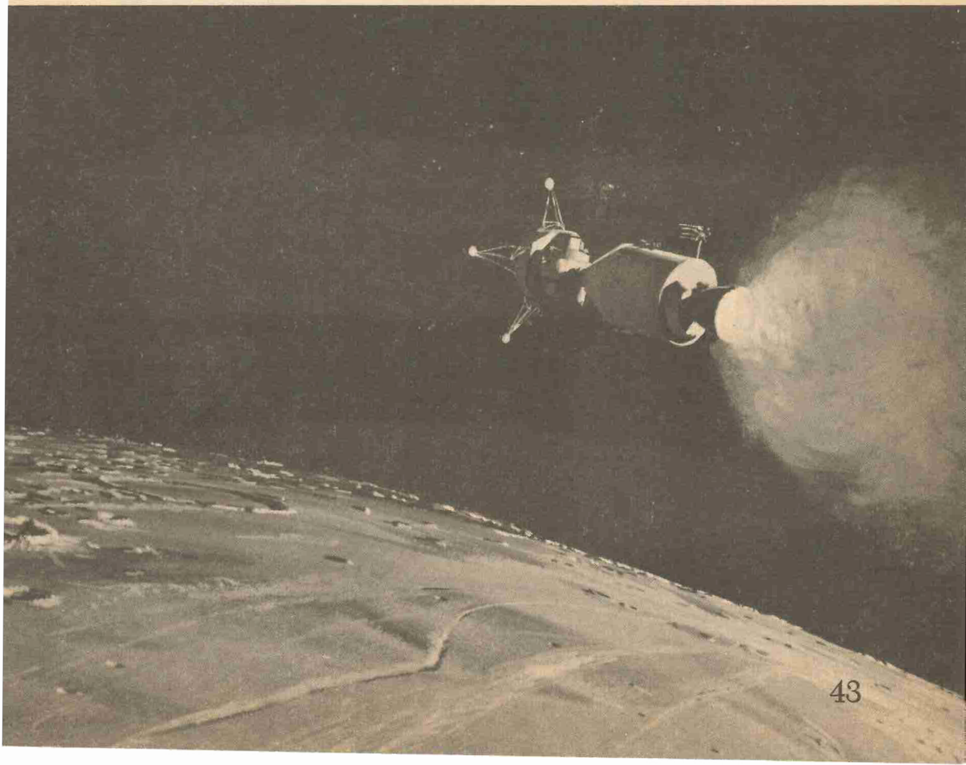
The Apollo spacecraft docks with the bug and pulls it free of the empty third-stage rocket case.



Carefully, the astronaut commander fires the service module engine. Since the exhaust blasts in the same direction the spacecraft is traveling, the opposite force of the thrust slows it down. At an altitude of about 100 miles above the surface of the moon, the speed of the spacecraft is adjusted so that it swings into a lunar orbit.

In a mission where all decisions are critical, it is difficult to weigh one against the other. At the

The service-module engine slows the spacecraft and guides it into a lunar orbit.

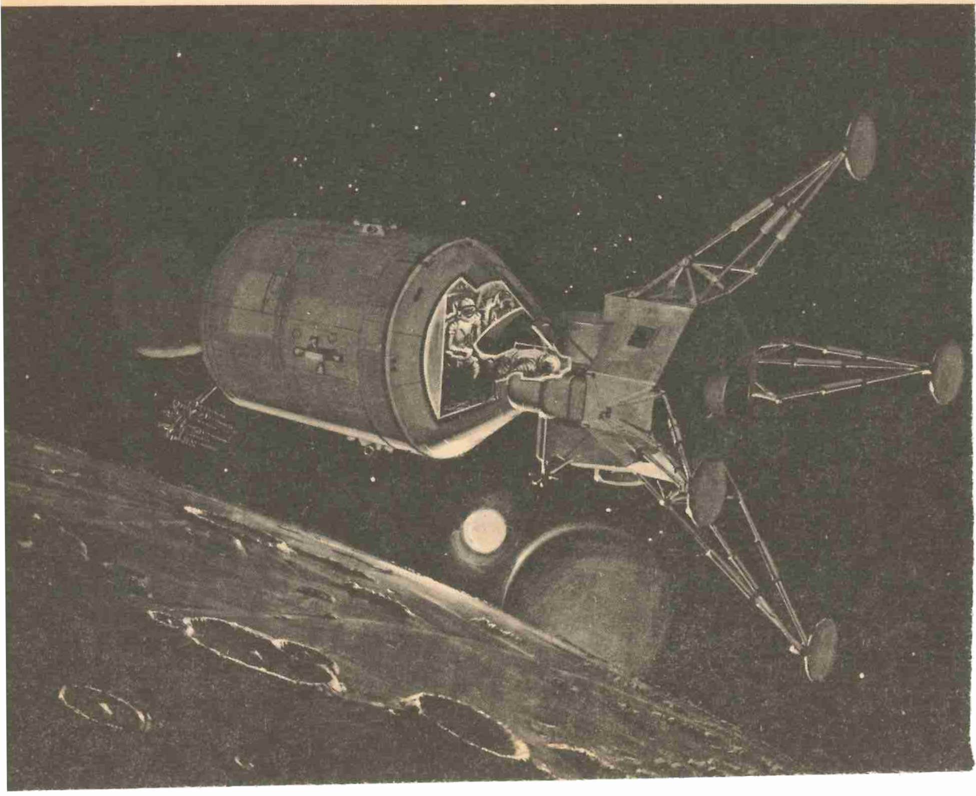


moment, as the three-module spacecraft circles the moon, another thorough all-systems check-out is made.

Now come the final arrangements for the lunar landing. Two of the astronauts crawl through the pressurized airlock and into the bug. By the time the spacecraft is in its second lunar orbit, all data has been coordinated across a quarter of a million miles of space.

In effect, with all systems operating "in the green,"

Cutaway view shows one astronaut entering the bug through the airlock located between the CM and LEM.



the astronauts are given the okay to land the bug on the moon.

They look down. Below them the gray, crater-pocked and fissure-scarred moonscape is both inviting and threatening. The Earth's giant satellite is 2,160 miles in diameter, or slightly more than one fourth the size of the Earth itself. Its gravity is one sixth that of Earth. On the moon, a ballplayer with a good arm could throw a baseball nearly half a mile.

There is no air or atmosphere on the moon – only a near vacuum of nothingness. Thus there is neither oxygen to breathe nor barometric pressure to hold a person together. An astronaut's salvation is his space suit, which is his substitute for the Earth's atmosphere.

A moon day is two Earth weeks long. And since the moon rotates on its axis at the identical rate that it orbits around the Earth, the same side of the moon always faces us. It gleams in the Earth's reflected light and in the glare from the sun.

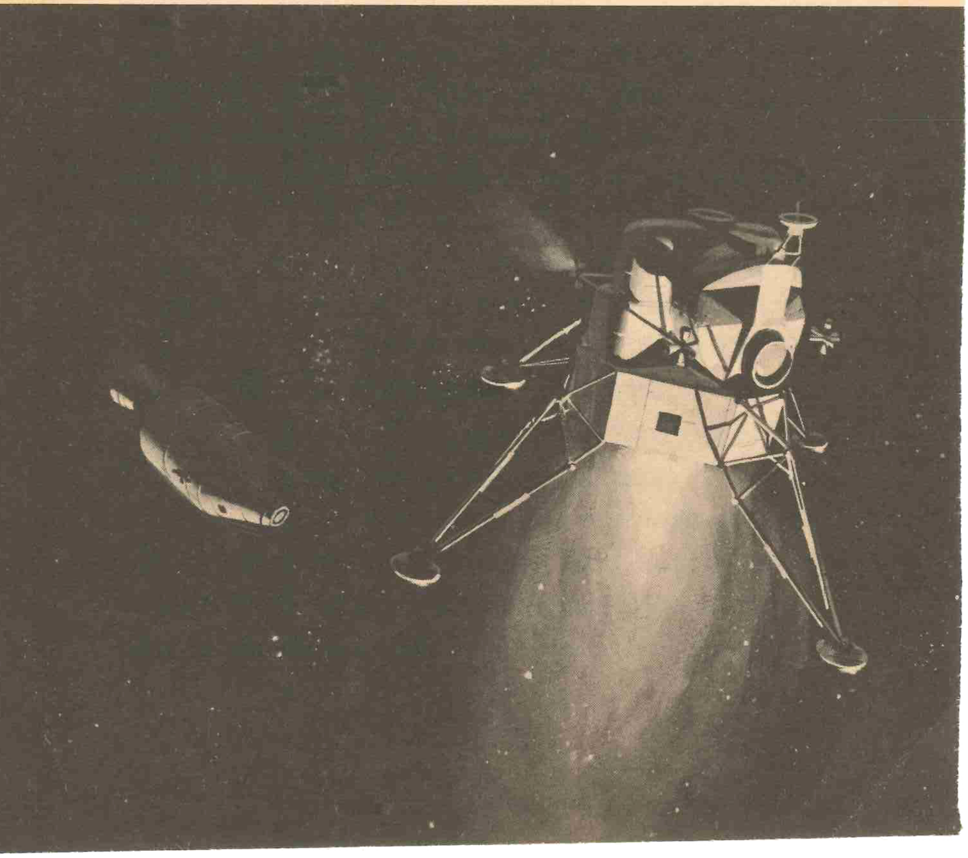
In the sunlight, the temperature on the moon's surface is over 240 degrees Fahrenheit. In the shadows, it drops immediately to approximately 270 degrees below zero. Without an atmosphere to soak up and diffuse heat and cold, temperatures on the moon exist only upon objects exposed. How mild or severe such temperatures are depends upon the heat-

absorbing or reflecting properties of the objects.

The astronauts are well versed in these and many other lunar statistics. But there is no time to delve into them now. At a relatively slow orbital speed of about 4,000 miles per hour, the Apollo spacecraft settles properly into its circling position 100 miles above the lunar equator.

At a precise and proper moment, the two astronauts

The bug separates from the main spacecraft and establishes its own lunar orbit.



inside the lunar excursion module cut loose from the command module. With a half-minute burst from the 10,500-pound-thrust engine, located in the spraddle-legged landing-stage section of the bug, they establish their own orbit around the moon. The command module in which the third astronaut still rides continues on its high orbit, and is soon lost from sight beyond the lunar horizon.

This separation of modules, each going its own way, may seem unwise and particularly hazardous in the vicinity of the moon. But it is, on the contrary, the only method by which there can be any hope that the astronauts will ever get back to Earth.

6. Man on the Moon

By careful maneuvering and a delicate use of power, the two astronauts send the bug into a lopsided, or an elliptical, orbit around the moon. Although following different paths, both the bug and the main spacecraft take two hours to circle the moon.

The bug's elliptical orbit is planned so that it will come down to a low point, or perigee, within ten miles of the moon's surface, then swing out to a high altitude, or apogee, of 100 miles. Every time the bug reaches its 100-mile apogee it meets the main spacecraft coming around in its own orbit.

It is of extreme importance that this be so. Something might go wrong with the landing plan. An unexpected equipment malfunction might occur. A low-altitude inspection of the moon might indicate it to be uninhabitable. For these, or a number of other reasons, the astronauts might wisely cancel the

landing phase of the mission. In such an instance, they would simply continue on in their orbit. Halfway around the moon, as they reached the apogee, they would catch up with the parent craft. Carefully they would rendezvous, closing up the few miles separating them. After coming together, or docking, the astronauts would crawl from the bug back into the command module, and prepare to head for home.

However, now everything seems to be going smoothly. On its first orbit the bug swoops down to within 50,000 feet of the moon. The two astronauts peer at the lunar landscape through large windows. They stare at the relatively smooth surface of the vast Sea of Tranquility, which straddles the lunar equator on the light side. It is a likely place to make their landing, just as planned.

"How does it look to you?" one of them asks over the interphone.

"Except for a few craters and crevasses, it looks fine. Have to get lower to make sure."

The decision is made to land. Already, though, the bug is swinging back out toward the high point of orbit. They will hold off on their landing until they come around the next time.

A while later their orbit meets that of the command module. They come so close, they feel as if they

could almost reach out and shake hands with the lone astronaut who remains inside the CM. They relay their plans, which are also relayed to Earth. Final small corrections in direction and velocity are made.

The bug swings into its second orbit, gradually descending toward the moon. It is made up of two stages: the landing or descent stage, and the lunar lift-off or ascent stage. Each has its own rocket motor.

Halfway around the moon, once more at the ten-mile altitude, the bug's descent-stage engine is turned on again. It slows the bug down below orbital speed. The moon's gravity pulls it toward the lunar surface.

On the way down, the two astronauts continue to check the operational systems within the bug. They also make close observations of the moon as it comes closer and closer. Three hundred feet above the moon they adjust the landing-stage rocket until the bug is hovering over it like a helicopter.

Even now, should anything be wrong, they can change their plans for landing. They can jettison the descent stage, fire the rocket in the bug's ascent stage, and head back for a rendezvous with the mother ship.

But the lunar surface is inviting, and everything is in proper working order. The men maneuver the bug horizontally for a few hundred feet until they pick out a most suitable-looking landing spot. Then,

at a speed of less than seven miles per hour, they gently set the bug down upon the moon. In the reduced gravity, the bug bounces a couple of times before coming to rest upon its metal legs.

Looking up, the astronauts can see the command and service module assembly orbiting directly overhead. Before long it disappears beyond the horizon. It is important for the men in the bug to maintain constant contact and communication with the

Three positions of the bug as it is guided into a lunar landing by the two astronauts.

astronaut in the parent craft. Yet they must do it via a very circuitous route. There is no atmosphere on the moon to propagate or "bend" electronic waves. They can only communicate by direct line of sight. When the mother ship is hidden on the far side of the moon, messages between the bug and the command module must be transmitted across a quarter of a million miles of space to Earth, then relayed back another quarter of a million miles to the receiver.

As the dust settles slowly around the bug, the astronauts get busy checking it out to be sure it is in proper shape for the return trip.

"All systems check."

One man stays inside the lunar excursion module. The other straps on a backpack life-support system. It consists of a power supply to run fans that will circulate air through his suit and to operate the communications system that maintains steady contact with his companion. It also carries a four-hour supply of oxygen. Heavy as that backpack seemed on Earth, now, in the one-sixth gravity of the moon, it is hardly noticeable. The whole pack can be recharged from the bug's own supply.

The astronaut leaves the bug and becomes the first man to plant his space boots upon lunar soil. Since it is daylight, the survival-pack ventilator labors hard

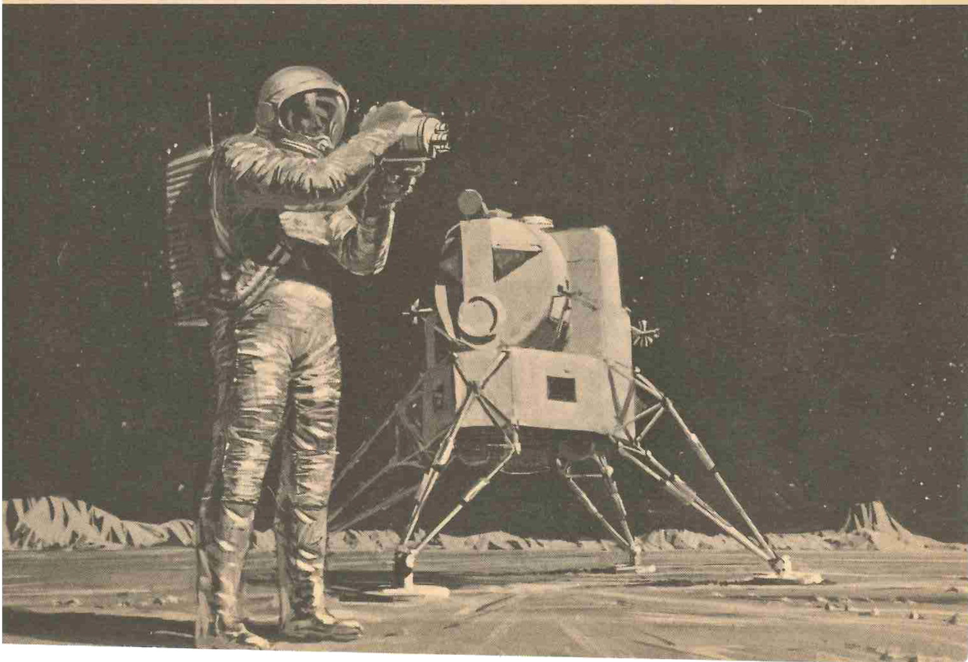
to keep the searing solar heat from cooking the man inside the space suit.

Beyond the lunar horizon, the Earth hangs in the sky like a giant blue-green ball with large areas covered by white cloud.

For the next couple of hours the astronaut roves the moon, always staying within sight of the parked bug. He carefully observes the terrain and makes measurements. He takes many photographs. He collects samples of rocks and soil and anything else that might be of interest to Earthbound scientists.

He pauses in his exploration and looks up to see

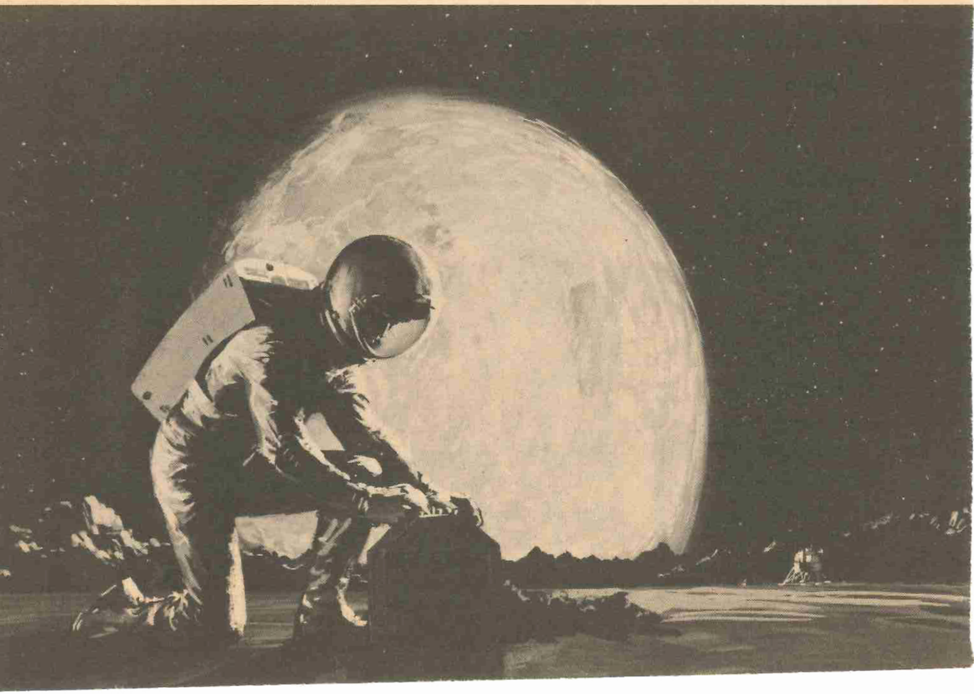
Shortly after landing, the first astronaut steps out upon the surface of the moon.



the mother vehicle arching through the black sky overhead, its metal sides gleaming in the sun.

Before the four hours are up, the astronaut returns to the bug, where his companion waits, eager to take his own turn. They change places, recharge the survival pack, and the second man sets off to do his own exploring. Among other things, he plants an array of electronic instruments on the moon. They will remain there, operating on self-charging solar batteries long after the astronauts are safely back on terra firma. The instrument packages will send back

With the earth as a backdrop, the second lunar explorer conducts his tests.



observations on solar rays, meteorite collisions, and various other lunar phenomena which the two men will not have time to investigate thoroughly.

Several more times the two astronauts take turns on the moon's surface. After completing their explorations, they both stay inside the bug to get a few hours of much-needed sleep.

When they have spent nearly twenty-four hours on the moon, it is time to prepare for the lift-off from Luna and the critical task of getting back to the command module.

7. Lift-off from Luna

The two astronauts in the bug begin the countdown for the return trip. It is relayed to the command module, out of sight on the far side of the moon. The lone astronaut there feeds it into his control system. Added data and computer help are being received from ground stations on Earth. Everything has to be exactly right. An error now could spell failure for the entire mission.

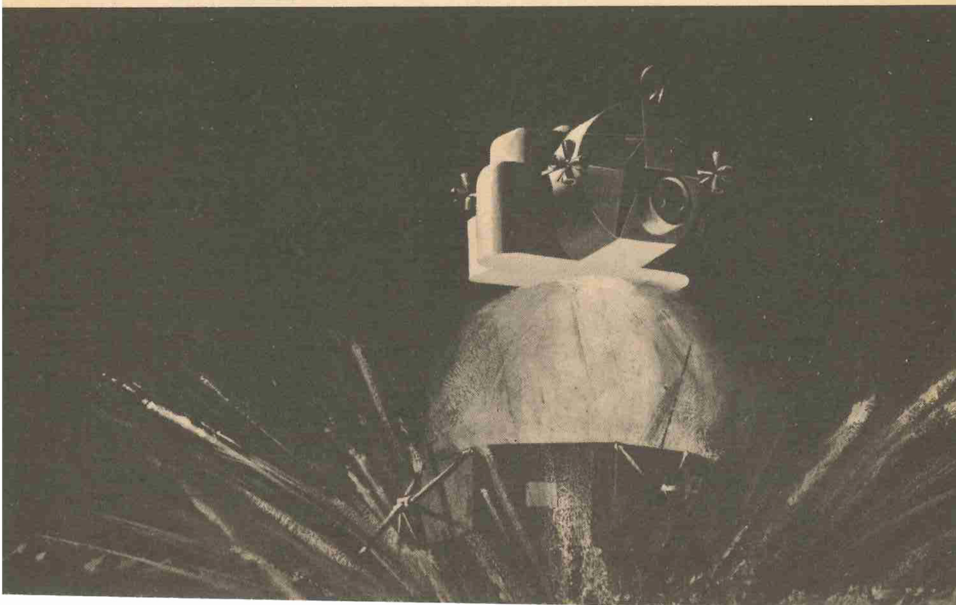
The countdown proceeds as the command module circles around the moon. Then it appears, coming up over the horizon. When it is directly overhead, the bug blasts off from the dry sand of the Sea of Tranquility. Having fulfilled its function, the exhausted landing stage is now dead weight. Using it as a launch platform, the upper half of the bug – the ascent stage – now blasts skyward, leaving the landing stage on the moon.

For a little over six minutes the 3000-pound-thrust engine of the ascent stage accelerates the lunar excursion module into a climbing trajectory. By the time the bug is at an altitude of ten miles the craft has reached an orbital velocity of about 4,000 miles per hour.

The plane of the new orbit is exactly like the one the bug was in prior to making the lunar landing. The position of the main vehicle in relation to the bug is also precisely what it was when they made the trial orbit some twenty-four hours earlier.

Everything works according to plan. At the proper moment, the ascent motor shuts down. The orbiting

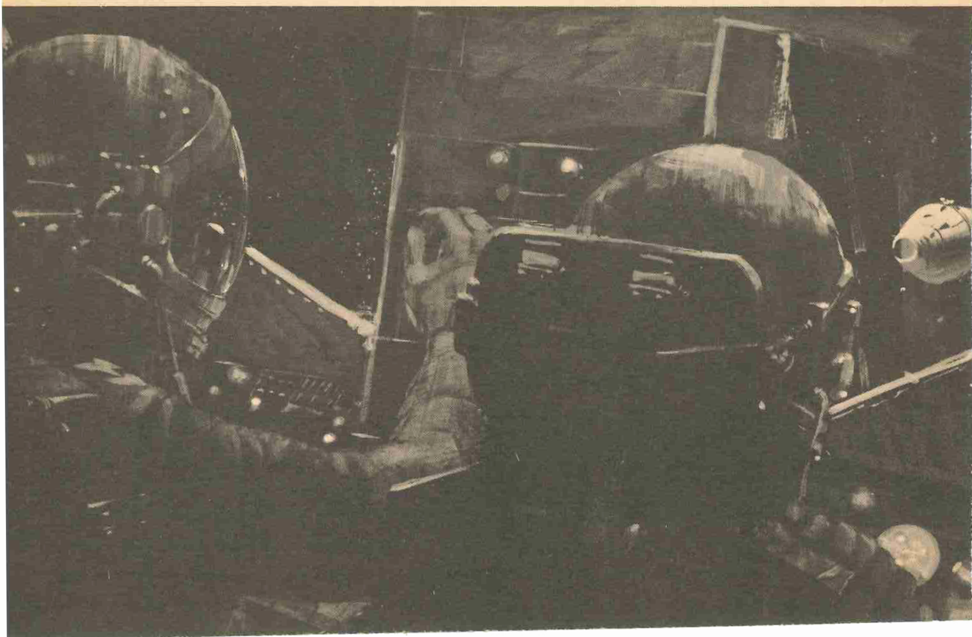
Leaving landing gear and used descent stage behind, LEM's ascent stage blasts off the moon for a rendezvous with the orbiting Apollo.



bug coasts toward its apogee. It is carefully aimed at the spot halfway around the moon where it will arrive at the altitude of the mother craft and match paths with it.

About an hour later this point is reached. The combined command and service modules grow larger in the eyes of the two astronauts in the bug. The relative speeds of the two spacecrafts differ by about seventy miles per hour, but the astronauts in the bug have carefully conserved some propellant in the ascent engine. Now, with short bursts of thrust, they compensate for this difference in the velocity of the two orbiting vehicles.

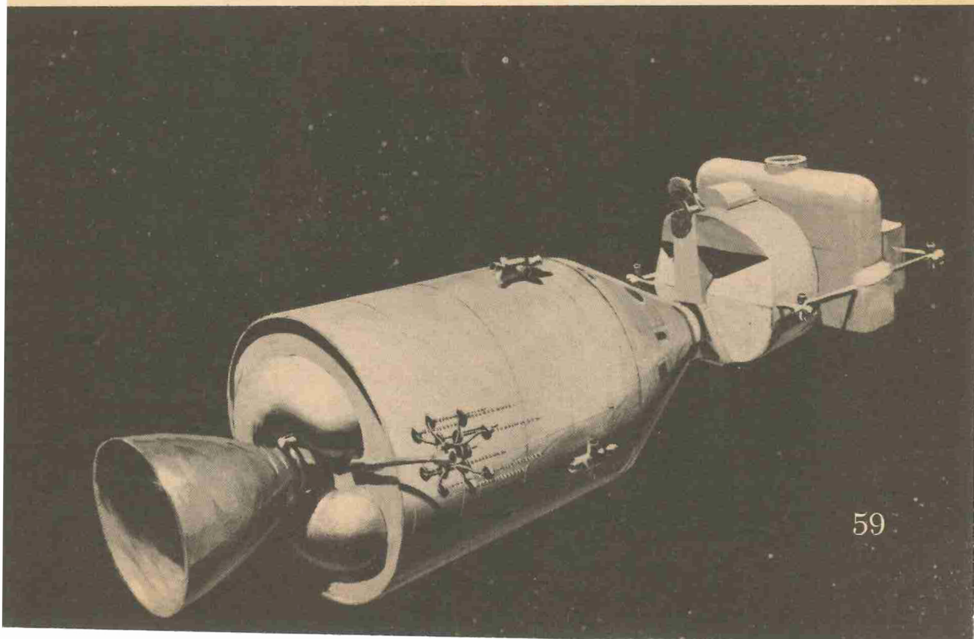
The astronauts maneuver the bug into position and dock with the orbiting command module.



Aided by radar and assorted automated guidance systems, the two spacecraft close the gap between them to a few hundred feet. Now the two astronauts in the bug take over control manually. Using the small ballistic rockets set in the sides of the lunar excursion module, they turn the bug and bring it gently nose to nose with the command module. Thus they complete the docking phase of the lunar-orbit rendezvous mission.

After the bug and the command module are rejoined, the two astronauts gather up their lunar samples, cameras, and records. They leave the bug through the airlock and happily take their places beside their grinning companion.

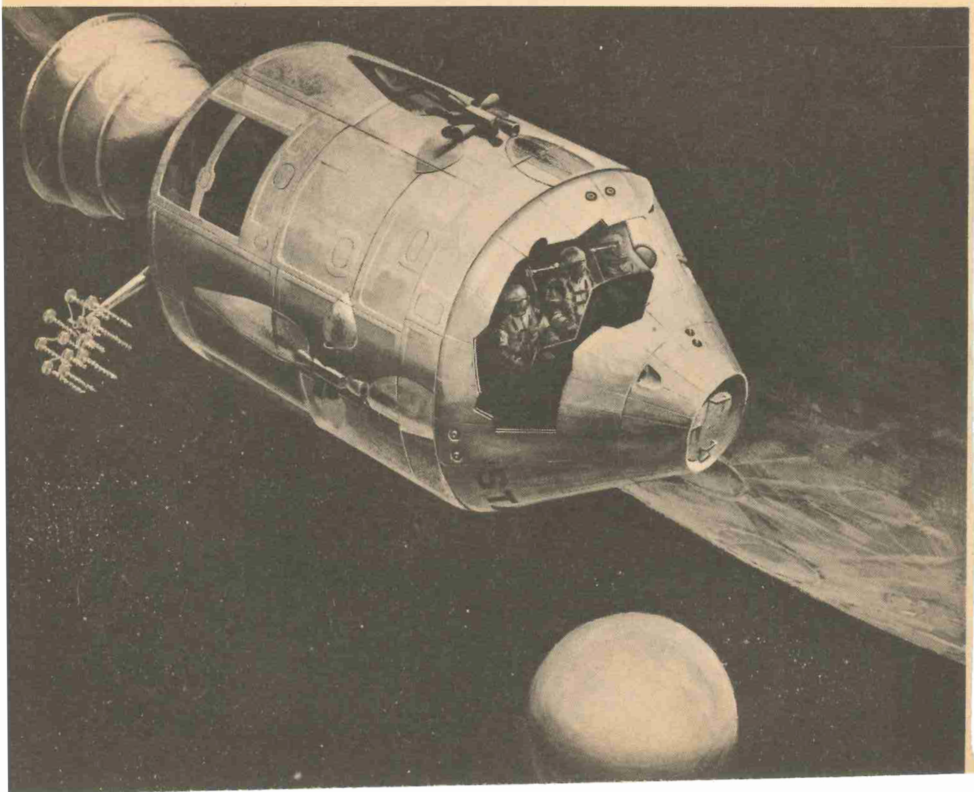
After docking with the Apollo command module, the two astronauts move from the bug back into the spacecraft.



Once they are safely back inside the command module, the astronauts cut the bug loose from the nose. Having done its job, it is no longer needed and would only be a hindrance in the attempt to get safely back to Earth, which is the next, most important, and final step of the Project Apollo mission.

As the bug drifts slowly off into its own orbit around the moon, the astronauts begin to decipher re-entry data being received from tracking and control stations

Having returned to their positions in the capsule, the three lunar astronauts prepare for the trip home.



on Earth. Once again they make a complete systems check-out. Some chores they must accomplish manually. Other systems are completely automated.

Yet despite the automation, there is room for applying human judgment where and when needed. This is one quality that makes men more valuable than machines and often more dependable. Being able to change one's mind at a moment's notice, to fit the action to the immediate situation, can solve many an unplanned problem.

Problems there surely are going to be in attempting a 25,000-mile-per-hour re-entry into the Earth's atmosphere. The least error in either mechanics or human judgment can be disastrous. One false action can turn the returning space vehicle into a flaming meteor, a pinch of ashes to mark the failure of a most courageous venture.

8. *Keyhole in the Cosmos*

The spacecraft is reduced now to the combination of command module and service module. The service module, with its 22,000-pound-thrust rocket engine, still contains a sufficient supply of liquid propellant to complete its final job.

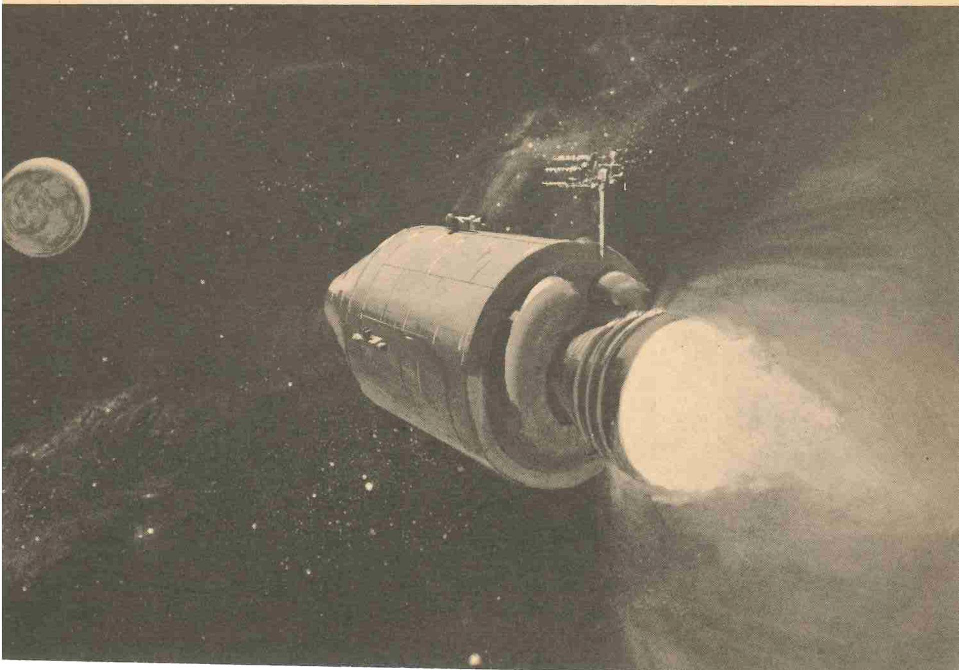
This job is to aim the CM back toward the Earth and to give it enough added velocity to escape the tug of the moon's gravity. The first item involves some very exacting help from the guidance system. The second item calls for less added propulsion than might be suspected.

Owing to the moon's weaker gravity, escape velocity away from it is less than 6,000 miles per hour. Already the spacecraft is in lunar orbit at nearly 4,000 miles per hour. To reach escape velocity requires an additional boost of about 2,000 miles per hour. This is no great chore for the service module rocket engine

to perform. It blazes for about two and a half minutes, increasing the vehicle's speed away from the moon. Then it shuts off. The spacecraft slips out of lunar gravity and heads Earthward.

The service module remains attached to the command module during most of the return trip to Earth. Periodic mid-course corrections must be made on the way home, and the power to make them remains in the service module engine. During the three-day coasting journey, the astronauts are assisted by the Earth-based network of radar and other ground tracking aids. Computers clack and hum. A precise

The service-module engine provides added thrust to escape lunar gravity and get the spacecraft headed toward Earth.

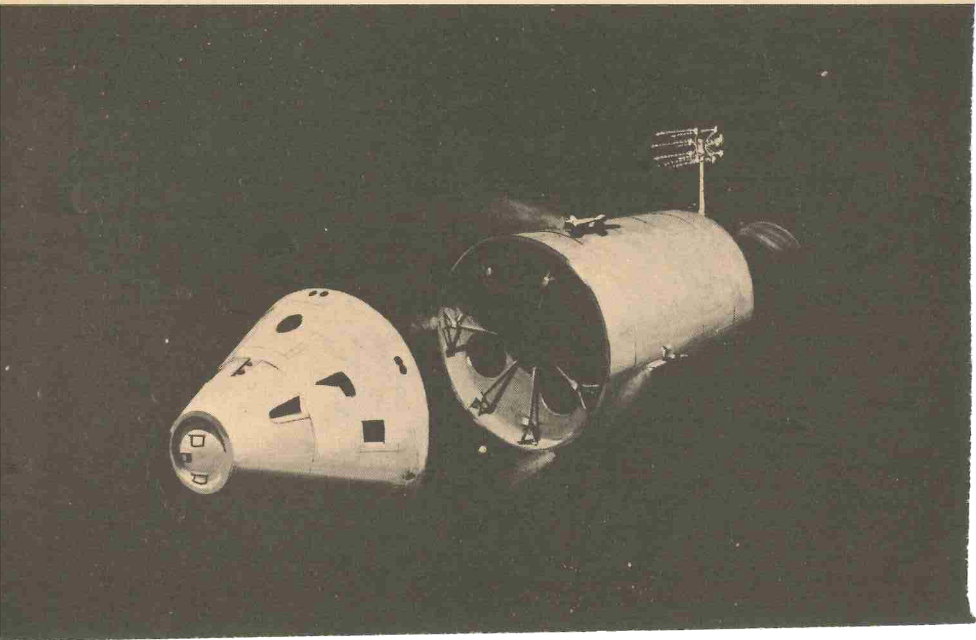


course is plotted. Exact guidance instructions for keeping on course are relayed to the capsule.

The command module must find and follow a forty-mile-deep by 300-mile-wide corridor through space. Trying to hit this re-entry "keyhole" in the endless expanse of the cosmos is as difficult as it is essential. Not only must the direction be pinpointed, but the angle of re-entry into Earth's atmosphere must be precise.

If the angle of approach is too shallow, the spacecraft will bounce or skip off the outer fringes of the atmosphere and hurtle back into space. Too steep

Before entering the Earth's atmosphere, the service module is jettisoned. The spacecraft has now been reduced to its smallest component – the manned capsule.



a plunge into the atmosphere would spell certain doom from the melting temperatures of friction heat and the enormous G forces of the sudden deceleration.

By using the service module engine, the astronauts make the final mid-course adjustments in trajectory. After this is done, and well before the beginning of actual re-entry into the atmosphere, the service module is jettisoned. It tumbles downward, burning up when it plunges into the atmosphere.

This leaves just the cone-shaped command module, with the three astronauts inside diving toward the distant Earth at a shallow angle.

A triple view shows the command module being rotated so that the blunt heat shield turns toward the Earth.

Owing to the constant tug of the Earth's gravity during the capsule's free fall through space, the velocity has steadily increased, until now the spacecraft approaches Earth at a fantastic 25,000 miles per hour. This is faster than the speed of some meteors, which become "shooting stars" of fiery vapor.

Using the small ballistic jets spaced around the capsule, the astronauts turn it around until the large blunt end is forward.

Looking like anything other than a spaceship, the capsule enters the first filmy fringes of the atmosphere. Securely harnessed into their couches and waiting, the three astronauts, riding backward, brace themselves for the sudden clutch of the atmosphere and for the friction heat that will threaten to consume the vehicle.

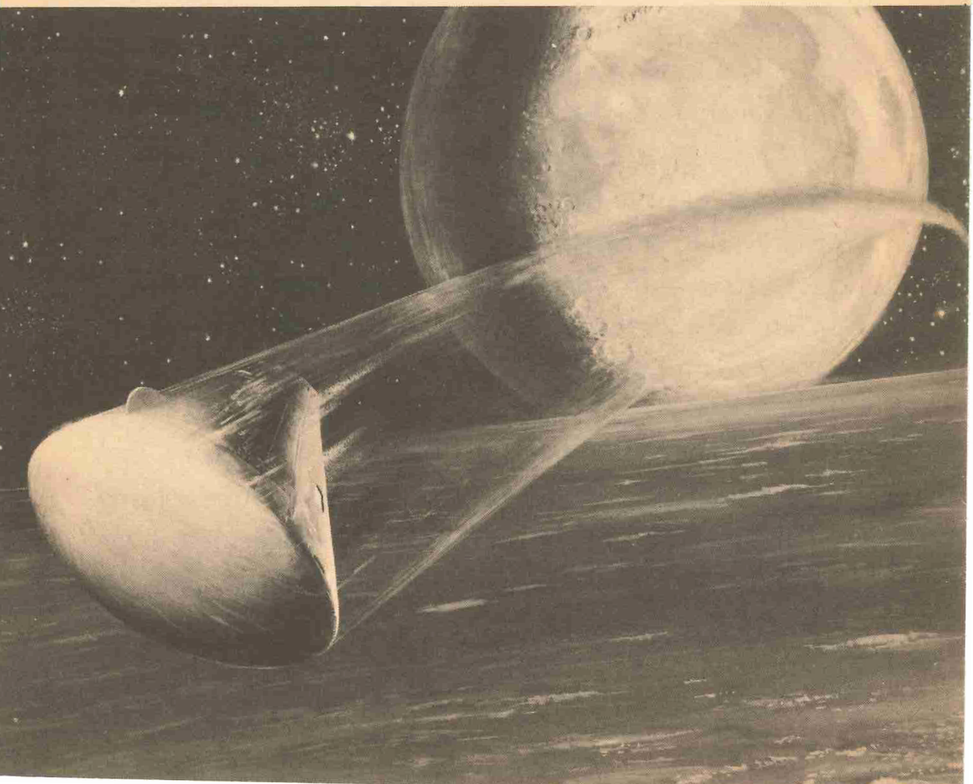
The re-entry is made at an angle of less than seven degrees. Thus the approach into the thickening atmosphere is gradual. Just below an altitude of 100 miles, as the grip of the atmosphere begins to slow their velocity, the G forces quickly increase, pinning the men to their contour couches.

Although a completely wingless craft, the capsule is so designed that there is a certain amount of lift generated by its shape and by the angle of its entry into the atmosphere. To a small degree, the command module can be "flown" and kept from plunging too steeply toward the Earth.

Still, the men hear the crackling sound of fire against the capsule sides. Flame and sparks flash past the windows. The astronauts cannot help but wonder tensely how long it will take the 6,000 degrees of friction heat to consume the thin walls of the capsule and get through to them.

But a very necessary and ingenious measure has been taken to prevent this. The capsule is enclosed in a plasticlike heat shield. This shield is particularly

Men and capsule survive the blazing re-entry into the Earth's atmosphere.



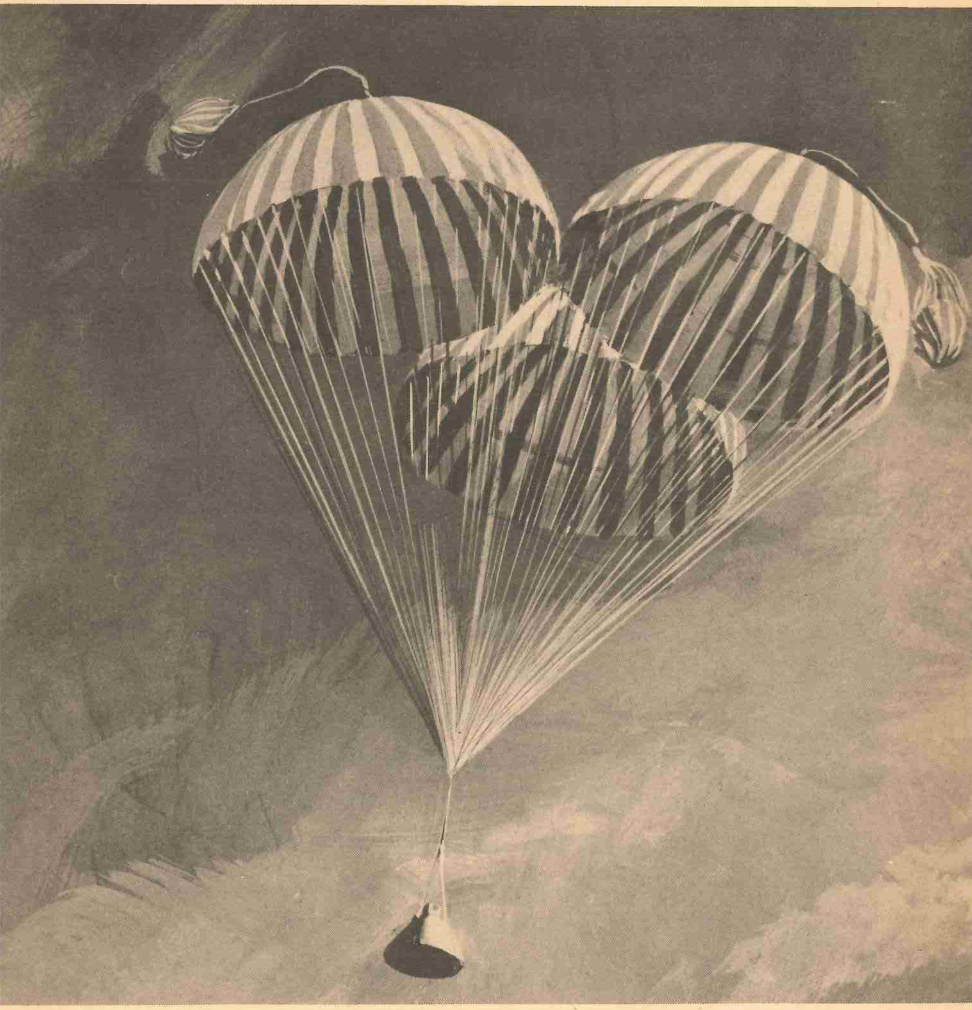
thick and heavy across the bottom of the cone, for that is where the heat is most severe. The shield is made of an ablative material. It is not actually heatproof. In fact, it is literally vaporized by the horrendous temperature. Melting and bubbling, it peels off the capsule, leaving a trail of flame and sparks.

This is exactly what it is supposed to do. As the capsule plunges deeper and deeper into the atmosphere, the shield is consumed and the friction heat begins to gnaw at the metal sides of the spacecraft. But it is too late to do real damage. By now the grasp of the atmosphere has slowed the capsule to subsonic speed. Friction heat is no longer a problem.

The altimeter needles unwind as the capsule drops earthward – 40,000 feet . . . 30,000 . . . 25,000 . . .

There is a metallic clack in the capsule dome overhead as the tip of the cone jettisons away. This is followed by a light explosion as a mortar charge ejects a thirteen-foot drogue parachute from its canister. There is a slight tug as the drogue trails out behind the descending Apollo spacecraft. Its drag helps to stabilize the capsule, dampening the pitch and sway.

At about 15,000 feet the drogue chute jettisons, and three small pilot chutes pop out, dragging out the three main parachutes. Each of these ribbon-type chutes has a diameter of eighty-eight feet. But these massive



Three giant parachutes lower the Apollo capsule gently and safely to Earth.

canopies do not immediately open wide. Instead, as they string out behind the capsule, their skirts remain tied together with reefing lines. Even reefed as they are, the additional drag helps to decelerate the falling spacecraft.

Then, at about a 10,000-foot altitude, a reefing cutter automatically severs the lines. The three gigantic orange-and-white ribbon chutes open fully, slowing the capsule to a gradual descent. The astronauts sigh inwardly. Certainly the worst is over.

As they drift on down toward the Earth, the men continue their assorted last-minute tasks. One astronaut is busy maintaining communication with search and rescue craft. Another quickly stows equipment and prepares for the impending splash. The third keeps occupied with other duties.

Each lies on his back in his contour couch, waiting. The Apollo capsule is designed to come down equally well on water or land. The flight plan for this mission calls for a water return. As the capsule sways slightly, one of the astronauts glances out the port and catches sight of the sea beneath them.

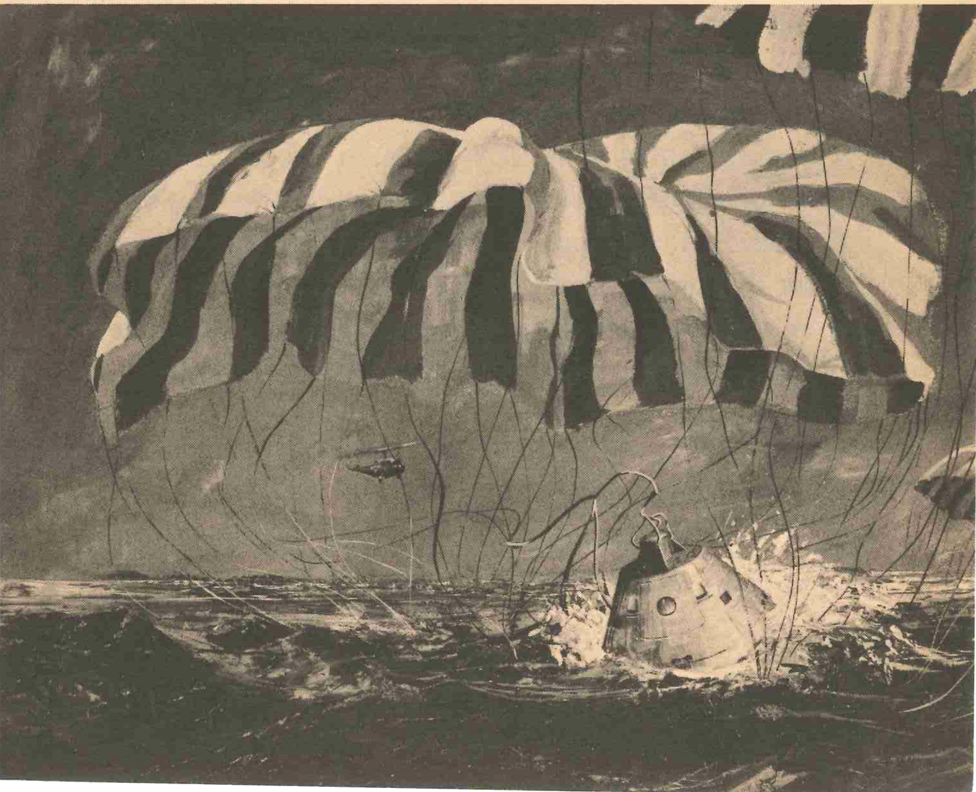
"It looks calm and fairly smooth," he says. "We're right on target!"

All three show their relief. Then they brace themselves. The four-ton capsule drifts slightly

sideways in a crosswind. It hits the water, skips once, then splashes to a rest. The parachutes jettison, in order not to drag the capsule through the water.

The three astronauts wait until all is quiet and settled down. As the capsule bobs easily in the ocean chop, they turn and grin at one another. Meanwhile automatic devices beam out homing signals to searching ships and aircraft.

Right on target, the Apollo capsule parachutes into the water.



The men make a final check of the command module and secure all items. Through the window they catch sight of a ship steaming toward them. Soon a helicopter is hovering overhead. It drops its team of frogmen, plus a considerable amount of equipment to help secure the capsule against the remote possibility of sinking.

They listen for a while to the men working outside. Then comes the signal that all is ready. The commander blows the hatch. Sunlight streams into the Project Apollo capsule. The three astronauts blink a few times; then they unhook their life-support paraphernalia, including oxygen hoses and physiological sensing devices.

One by one they climb out of the capsule and into a waiting rubber raft. Each removes his helmet and sucks in his first natural breath in a week, relishing the familiar feel of normal one-G gravity. The astronauts greet the frogmen, who, with great restraint, refrain from asking questions. These must all be saved for the official debriefing aboard the aircraft carrier, now fast approaching.

The astronauts laugh from sheer joy of having successfully completed their mission. Then they lean back and gaze into the endless sky through which they have just returned. They welcome a few moments of

quiet, a bit of leisure before the parades and celebrations begin. How fully they can use a little free time.

They have been to the moon. They have come back.

After all, there are a few things they would like to talk about themselves . . . a few things they would like to think about!

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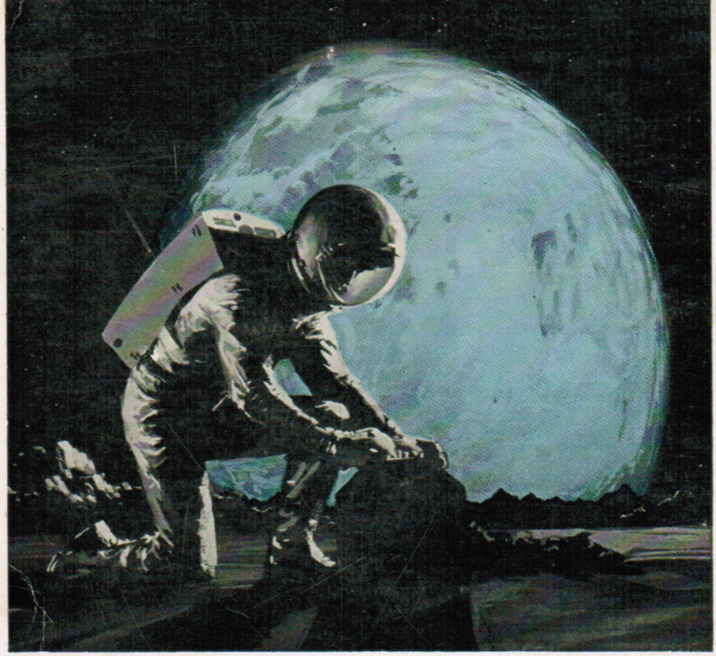

It is no longer a dream. In the near future three astronauts will blast off on man's greatest adventure in space—a trip to the moon and back.

What kind of giant space vehicle will carry them there? How will their moon suits give them the protection they need? What are the hazards they will face in their 240,000-mile dash to the moon? What conditions will they find on the moon?

Step by step, here is the exciting account of Project Apollo—mission to the moon!